REPORT

OF THE

TWENTY-FIRST MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT IPSWICH IN JULY 1851.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1852.

PRINTED BY

RICHARD TAYLOR AND WILLIAM FRANCIS,

RED LION COURT, FLEET STREET.

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The Editors of the preceding Notices consider themselves responsible only for the fidelity with which the views of the Authors are abstracted.

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other Institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

ADMISSION OF MEMBERS AND ASSOCIATES.

All Persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions, shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee, shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

COMPOSITIONS, SUBSCRIPTIONS, AND PRIVILEGES.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

Associates for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes :—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.

2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.

3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]

4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]

5. Associates for the year, subject to the payment of One Pound.

6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz. :—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845 a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members, who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain,* at one-third of the Publication Price. Application to be made (by letter) to Mr. R. Taylor, Red Lion Court, Fleet Street, London.

Subscriptions shall be received by the Treasurer or Secretaries.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons :—

1. Presidents and Officers for the present and preceding years, with authors of Reports in the Transactions of the Association.

2. Members who have communicated any Paper to a Philosophical Society, which has been printed in its Transactions, and which relates to such subjects as are taken into consideration at the Sectional Meetings of the Association.

3. Office-bearers for the time being, or Delegates, altogether not exceeding three in number, from any Philosophical Society publishing Transactions.

4. Office-bearers for the time being, or Delegates, not exceeding three, from Philosophical Institutions established in the place of Meeting, or in any place where the Association has formerly met.

5. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing for the meeting of the year by the President and General Secretaries.

6. The Presidents, Vice-Presidents, and Secretaries of the Sections are *ex officio* members of the General Committee for the time being.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects, shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee, unless previously recommended by the Committee of Recommendations.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

I. Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S.L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
Sir T. MAKDOUGALL BRISBANE, K.C.B., D.C.L., F.R.SS. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robison, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chan. Univ. London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres.R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.

SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich. Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Prof. Owen, M.D., F.R.S. Prof. Powell, F.R.S.	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. The Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. Henry Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, Pres. Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Professor Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E. EDINBURGH, July 31, 1850.	Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. Right. Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., K.C.B., G.C.H., D.C.L., F.R.S., Pres. R.S.E. Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal. IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, M.R.I.A., Pres. R.S. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's Coll. Belfast. Rev. T. R. Robinson, D.D., Pres.R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.

II. Table showing the Names of Members of the British Association who have served on the Council in former years.

Acland, Sir Thomas D., Bart., M.P., F.R.S.
Acland, Professor H. W., B.M., F.R.S.
Adamson, John, Esq., F.L.S.
Adare, Edwin, Viscount, M.P., F.R.S.
Ainslie, Rev. Gilbert, D.D., Master of Pembroke Hall, Cambridge.
Airy, G. B., D.C.L., F.R.S., Astronomer Royal.
Alison, Professor W. P., M.D., F.R.S.E.
Ansted, Professor D. T., M.A., F.R.S.
Argyll, George Douglas, Duke of, F.R.S.
Arnott, Neil, M.D., F.R.S.
Ashburton, William Bingham, Lord, D.C.L.
Babbage, Charles, Esq., F.R.S.
Babington, C. C., Esq., F.L.S.
Baily, Francis, Esq., F.R.S.
Balfour, Professor John H., M.D.
Barker, George, Esq., F.R.S.
Bengough, George, Esq.
Bentham, George, Esq., F.L.S.
Bigge, Charles, Esq.
Blakiston, Peyton, M.D., F.R.S.
Boileau, Sir John P., Bart., F.R.S.
Boyle, Right Hon. David, Lord Justice-General, F.R.S.E.
Brand, William, Esq.
Brewster, Sir David, K.H., D.C.L., LL.D., F.R.S.
Breadalbane, John, Marquis of, K.T., F.R.S.
Brisbane, General Sir Thomas M., Bart., K.C.B., G.C.H., D.C.L., F.R.S.
Brown, Robert, D.C.L., F.R.S., President of the Linnean Society.
Brunel, Sir M. I., F.R.S.
Buckland, Very Rev. William, D.D., Dean of Westminster, F.R.S.
Burlington, William, Earl of, M.A., F.R.S., Chancellor of the University of London.
Bute, John, Marquis of, K.T.
Carlisle, George William Frederick, Earl of, F.G.S.
Carson, Rev. Joseph.
Cathcart, Lieut.-General, Earl of, K.C.B., F.R.S.E.
Chalmers, Rev. T., D.D., late Professor of Divinity, Edinburgh.
Chance, James, Esq.
Chester, John Graham, D.D., Lord Bishop of.
Christie, Professor S. H., M.A., Sec. R.S.
Clare, Peter, Esq., F.R.A.S.
Clark, Rev. Professor, M.D., F.R.S. (Cambridge).
Clark, Henry, M.D.
Clark, G. T., Esq.
Clear, William, Esq.
Clerke, Major Shadwell, K.H., R.E., F.R.S.
Clift, William, Esq., F.R.S.
Cobbold, John Chevalier, Esq., M.P.
Colquhoun, J. C., Esq., M.P.
Conybeare, Very Rev. W. D., Dean of Llandaff, M.A., F.R.S.
Corrie, John, Esq., F.R.S.
Currie, William Wallace, Esq.
Dalton, John, D.C.L., F.R.S.
Daniell, Professor J. F., F.R.S.
Dartmouth, William, Earl of, D.C.L., F.R.S.
Darwin, Charles, Esq., F.R.S.
Daubeny, Professor Charles G. B., M.D., F.R.S.
De la Beche, Sir Henry T., F.R.S., Director-General of the Geological Survey of the United Kingdom.
Dillwyn, Lewis W., Esq., F.R.S.
Drinkwater, J. E., Esq.
Durham, Edward Maltby, D.D., Lord Bishop of, F.R.S.
Egerton, Sir Philip de M. Grey, Bart., F.R.S.
Eliot, Lord, M.P.
Ellesmere, Francis, Earl of, F.G.S.
Estcourt, T. G. B., D.C.L.
Faraday, Professor, D.C.L., F.R.S.
Fitzwilliam, Charles William, Earl, D.C.L., F.R.S.
Fleming, W., M.D.
Fletcher, Bell, M.D.
Forbes, Charles, Esq.
Forbes, Professor Edward, F.R.S.
Forbes, Professor J. D., F.R.S., Sec. R.S.E.
Fox, Robert Were, Esq., F.R.S.
Gassiot, John P., Esq., F.R.S.
Gilbert, Davies, D.C.L., F.R.S.
Graham, Professor Thomas, M.A., F.R.S.
Gray, John E., Esq., F.R.S.
Gray, Jonathan, Esq.
Gray, William, jun., Esq., F.G.S.
Green, Professor Joseph Henry, F.R.S.
Greenough, G. B., Esq., F.R.S.
Grove, W. R., Esq., F.R.S.
Hallam, Henry, Esq., M.A., F.R.S.
Hamilton, W. J., Esq., Sec.G.S.
Hamilton, Sir William R., Astronomer Royal of Ireland, M.R.I.A.
Harcourt, Rev. William Vernon, M.A., F.R.S.
Hardwicke, Charles Philip, Earl of, F.R.S.
Harford, J. S., D.C.L., F.R.S.
Harris, Sir W. Snow, F.R.S.
Harrowby, The Earl of.
Hatfeild, William, Esq., F.G.S.
Henslow, Rev. Professor, M.A., F.L.S.
Henry, W. C., M.D., F.R.S.
Herbert, Hon. and Very Rev. William, late Dean of Manchester, LL.D., F.L.S.
Herschel, Sir John F. W., Bart., D.C.L., F.R.S.
Heywood, Sir Benjamin, Bart., F.R.S.
Heywood, James, Esq., M.P., F.R.S.
Hill, Rev. Edward, M.A., F.G.S.
Hodgkin, Thomas, M.D.
Hodgkinson, Professor Eaton, F.R.S.
Hodgson, Joseph, Esq., F.R.S.
Hooker, Sir William J., LL.D., F.R.S.
Hope, Rev. F. W., M.A., F.R.S.
Hopkins, William, Esq., M.A., F.R.S.
Horner, Leonard, Esq., F.R.S., F.G.S.
Hovenden, V. F., Esq., M.A.
Hutton, Robert, Esq., F.G.S.
Hutton, William, Esq., F.G.S.
Ibbetson, Capt. L. L. Boscawen, K.R.E., F.G.S.
Inglis, Sir Robert H., Bart., D.C.L., M.P., F.R.S.
Jameson, Professor R., F.R.S.
Jeffreys, John Gwyn Jeffreys, Esq.
Jenyns, Rev. Leonard, F.L.S.
Jerrard, H. B., Esq.
Johnston, Right Hon. William, Lord Provost of Edinburgh.
Johnston, Professor J. F. W., M.A., F.R.S.

Keleher, William, Esq.
Kelland, Rev. Professor P., M.A.
Lansdowne, Henry, Marquis of, D.C.L., F.R.S.
Lardner, Rev. Dr.
Latham, R. G., M.D., F.R.S.
Lee, Very Rev. John, D.D., F.R.S.E., Principal of the University of Edinburgh.
Lee, Robert, M.D., F.R.S.
Lefevre, Right Hon. Charles Shaw, Speaker of the House of Commons.
Lemon, Sir Charles, Bart., M.P., F.R.S.
Liddell, Andrew, Esq.
Lindley, Professor John, Ph.D., F.R.S.
Listowel, The Earl of.
Lloyd, Rev. Bartholomew, D.D., late Provost of Trinity College, Dublin.
Lloyd, Rev. Professor, D.D., Provost of Trinity College, Dublin, F.R.S.
Lubbock, Sir John W., Bart., M.A., F.R.S.
Luby, Rev. Thomas.
Lyell, Sir Charles, M.A., F.R.S.
MacCullagh, Professor, D.C.L., M.R.I.A.
Macfarlane, The Very Rev. Principal.
MacLeay, William Sharp, Esq., F.L.S.
MacNeill, Professor Sir John, F.R.S.
Malcolm, Vice Admiral Sir Charles, K.C.B.
Manchester, James Prince Lee, D.D., Lord Bishop of.
Meynell, Thomas, Jun., Esq., F.L.S.
Middleton, Sir William, F. F., Bart.
Miller, Professor W. H., M.A., F.R.S.
Moillet, J. L., Esq.
Moggridge, Matthew, Esq.
Moody, J. Sadleir, Esq.
Moody, T. H. C., Esq.
Moody, T. F., Esq.
Morley, The Earl of.
Moseley, Rev. Henry, M.A., F.R.S.
Mount-Edgecumbe, Ernest Augustus, Earl of.
Murchison, Sir Roderick I., G.C.S., F.R.S.
Neill, Patrick, M.D., F.R.S.E.
Nicol, D., M.D.
Nicol, Rev. J. P., LL.D.
Northumberland, Hugh, Duke of, K.G., M.A., F.R.S.
Northampton, Spencer Joshua Alwyne, Marquis of, V.P.R.S.
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Norwich, Edward Stanley, D.D., F.R.S., late Lord Bishop of.
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Orpen, J. H., LL.D.
Owen, Professor Richard, M.D., F.R.S.
Oxford, Samuel Wilberforce, D.D., Lord Bishop of, F.R.S., F.G.S.
Osler, Follett, Esq.
Palmerston, Viscount, G.C.B., M.P.
Peacock, Very Rev. George, D.D., Dean of Ely, F.R.S.
Peel, Rt. Hon. Sir Robert, Bart., M.P., D.C.L., F.R.S.
Pendarves, E., Esq., F.R.S.
Phillips, Professor John, F.R.S.
Porter, G. R., Esq.
Powell, Rev. Professor, M.A., F.R.S.
Prichard, J. C., M.D., F.R.S.
Ramsay, Professor W., M.A.
Reid, Lieut.-Col. Sir William, F.R.S.
Rendlesham, Rt. Hon. Lord, M.P.
Rennie, George, Esq., V.P.R.S.
Rennie, Sir John, F.R.S.
Richardson, Sir John, M.D., F.R.S.
Ritchie, Rev. Professor, LL.D., F.R.S.
Robinson, Rev. J., D.D.
Robinson, Rev. T. R., D.D., M.R.I.A.
Robison, Sir John, late Sec.R.S.Edin.
Roche, James, Esq.
Roget, Peter Mark, M.D., F.R.S.
Ronalds, Francis, F.R.S.
Rosebery, The Earl of, K.T., D.C.L., F.R.S.
Ross, Capt. Sir James C., R.N., F.R.S.
Rosse, William, Earl of, M.R.I.A., President of the Royal Society.
Royle, Professor John F., M.D., F.R.S.
Russell, James, Esq.
Russell, J. Scott, Esq.
Sabine, Lieut.-Colonel Edward, R.A., Treas. R.S.
Saunders, William, Esq., F.G.S.
Sandon, Lord.
Scoresby, Rev. W., D.D., F.R.S.
Sedgwick, Rev. Professor Adam, M.A., F.R.S.
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St. David's, Connop Thirlwall, D.D., Lord Bishop of.
Stevelly, Professor John, LL.D.
Strang, John, Esq.
Strickland, H. E., Esq., F.G.S.
Sykes, Lieut.-Colonel W. H., F.R.S.
Symonds, B. P., D.D., late Vice-Chancellor of the University of Oxford.
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Tayler, Rev. J. J.
Taylor, John, Esq., F.R.S.
Taylor, Richard, Jun., Esq., F.G.S.
Thompson, William, Esq., F.L.S.
Tindal, Captain, R.N.
Tod, James, Esq., F.R.S.E.
Traill, J. S., M.D.
Turner, Edward, M.D., F.R.S.
Turner, Samuel, Esq., F.R.S., F.G.S.
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Western, Thomas Burch, Esq.
Wharncliffe, John Stuart, Lord, F.R.S.
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Wills, William.
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THE GENERAL TREASURER'S ACCOUNT from 31st of July

RECEIPTS.

	£	s.	d.	£	s.	d.
To Balance brought on from last account				404	8	9
Life Compositions at Edinburgh and since				120	0	0
Annual Subscriptions at Edinburgh and since				261	2	0
Associates' Subscriptions at Edinburgh				510	0	0
Ladies' Tickets at Edinburgh				273	0	0
Book Composition				5	0	0
Dividend on Stock (six months' interest on £3500 three per cent. Consols)				50	19	5
From the Sale of Publications, viz. Reports, Catalogues of Stars, &c.:—						
Volume 1	0	11	2			
2	0	12	0			
3	1	0	0			
4	1	7	0			
5	1	18	0			
6	1	7	6			
7	0	5	0			
8	1	16	0			
9	4	0	0			
10	0	13	6			
11	0	19	3			
12	1	0	0			
13	3	13	4			
14	4	6	0			
15	5	17	6			
16	12	3	0			
17	8	18	6			
18	42	7	3			
19	7	0	0			
British Association Catalogue of Stars	43	7	9			
Lalande's Catalogue of Stars	3	7	4			
Lacaille's Catalogue of Stars	0	18	0			
Dove's Isothermal Lines	22	16	0			
Lithograph Signatures	0	15	0			
				170	19	1
				£1795	9	3

Audited and found correct,

J. W. GILBART,
JOHN GASSIOT, } *Auditors.*
JOHN LEE,

1850 (at Edinburgh) to 2nd of July 1851 (at Ipswich).

PAYMENTS.

	£	s.	d.	£	s.	d.
For Sundry Printing, Advertising, Expenses of Meeting at Edinburgh, and Petty Disbursements made by the General Treasurer and Local Treasurers				212	12	9
Printing, &c., 18th volume				310	13	0
Engraving, 19th volume				12	8	0
Salaries, Assistant General Secretary and Accountant, six months				175	0	0
Maintaining the Establishment at Kew Observatory :—						
Balance of Grant of 1849	38	15	2			
On Account of Grant for 1850	270	7	0			
				309	2	2
On account of Grant—						
For Experiments on the Theory of Heat				20	1	1
Periodical Phænomena of Animals and Plants				5	0	0
Vitality of Seeds				5	6	4
Influence of the Solar Radiations on Chemical Combinations, &c.				30	0	0
Ethnological inquiries				12	0	0
Researches on the Annelida				10	0	0
Balance at the Bankers	579	12	3			
Ditto in the hands of the General Treasurer and Local Treasurers	113	13	8			
				693	5	11
				£1795	9	3

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Rev. P. S. Henry, D.D., President of Queen's College, Belfast.
Rev. T. R. Robinson, D.D., Pres.R.I.A., F.R.A.S.
George Gabriel Stokes, F.R.S., Lucasian Professor of Mathematics in the University of Cambridge.
John Stevelly, LL.D., Professor of Natural Philosophy in Queen's College, Belfast.

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Robert Patterson, Esq.

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Secretaries.—Dr. E. Lankester, F.R.S. Professor Allman, M.R.I.A. F. W. Johnson, Esq.

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Vice-Presidents.—James Nasmyth, Esq. J. Scott Russell, M.A., F.R.S. William Fairbairn, F.R.S.

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Report of the Proceedings of the Council in 1850–51, as presented to the General Committee at Ipswich, Wednesday, July 2, 1851.

I. With reference to the subjects referred to the Council by the General Committee assembled in Edinburgh, the Council have to report as follows:—

1. Having communicated with Dr. Robinson, on whose suggestion the General Committee directed that application should be made to the Admiralty for the publication of the Reports of their Committee on Metals, and having also communicated with the Admiralty,—the Council have requested Mr. James Nasmyth, who was himself one of the members of the Metal Committee, to undertake the task of drawing up an abstract of the principal matters contained in its reports, to be presented to the British Association at Ipswich, or at the Meeting in 1852; and the Admiralty, at the request of the Council, have consented to place the three volumes of the Reports in Mr. Nasmyth's hands for this purpose.

2. In compliance with the direction that a Committee should be appointed for the purpose of waiting on Her Majesty's Government, to request that some means be taken to ensure to the science of Natural History an effective representation in the Trusteeship of the British Museum, the Council proceeded to name a Committee; but in consequence of one of two recent vacancies in the Trusteeship of the British Museum having been filled up by the appointment of a distinguished Naturalist, Sir Philip Grey Egerton, Bart., the Committee have not deemed it requisite to make the application to Government contemplated by the General Committee.

3. On the subject of an application to Government to institute a Statistical Survey relative to the extent and prevalence of Infantile Idiotcy, the Council having ascertained that the importance of such an inquiry had already been pressed on the attention of Government by the Statistical Society of London, and that the representation had been very favourably received, have forborne to take any further step for the present.

4. The Committee appointed at Edinburgh, for the purpose of urging on Government the completion of the Geographical Survey of Scotland, recommended by the British Association at their former meeting at Edinburgh in 1834, have presented a Memorial to Lord John Russell, showing that, in the interval of 16 years elapsed since the former meeting of the Association in Edinburgh, but a single county, namely, Wigtonshire (less than a sixtieth part of Scotland), has been mapped; that the surveying force employed in Scotland, and the funds allotted to that portion of the United Kingdom, have been very much less than that allotted to either England or Ireland; and that on the present scale of procedure upwards of 50 years must elapse before the map of Scotland can be completed. The Memorial further solicits Her Majesty's Government to endeavour to obtain from Parliament an annual grant adequate to the completion of the map in the next 10 years. The Memorial was courteously received by the First Lord of the Treasury, and has been followed by the appointment of a Committee of the House of Commons to inquire into the whole subject of the survey of North Britain.

II. Since the last report of the Council to the General Committee was presented at Edinburgh, the reply of Her Majesty's Government has been received to the Memorial drawn up by Dr. Robinson, President of the British Association, with the concurrence of the Earl of Rosse, President of the

Royal Society, and presented to Lord John Russell, recommending the establishment of a Reflecting Telescope of large optical power, at a suitable station, for the systematic observation of the Nebulæ of the Southern Hemisphere. The reply is as follows:—

"Treasury Chambers, 14th August, 1850.

"Sir,—I am commanded by the Lords Commissioners of Her Majesty's Treasury to acquaint you, that your Memorial of the 3rd ult., addressed to Lord John Russell, applying on behalf of the British Association for the Advancement of Science for the 'establishment, in some fitting part of Her Majesty's dominions, of a powerful reflecting telescope, and for the appointment of an observer charged with the duty of employing it in a review of the Nebulæ of the Southern Hemisphere,' has been referred by his Lordship to this Board; and I am directed to inform you, with reference thereto, that while My Lords entertain the same views as those expressed by you as to the interest attaching to such observations, yet it appears to their Lordships that there is so much difficulty attending on the arrangements which alone could render any scheme of this kind really beneficial to the purposes of science, that they are not prepared to take any steps without much further consideration.

"I am, Sir, &c.,
"Your obedient Servant,
"G. Cornewall Lewis."

The Council have communicated a copy of this reply to the President and Council of the Royal Society, who had concurred in the recommendation; accompanying the communication with an assurance that the British Association will not lose sight of this important object, and requesting the continued co-operation of the Royal Society. The specific difficulties alluded to in this letter have not been communicated by the Government; but the Council entertain the hope that they are not of such a nature that time and further consideration may not remove them. The Council will now conclude the duty entrusted to them with the expression of their belief that the time is not far distant when the subject may be again, and successfully, brought under the consideration of Her Majesty's Ministers.

III. For the purpose of obtaining from the Authorities of the Ordnance Department replies which might be satisfactory to the General Committee, relative to the progress which had been made towards the publication, recommended in the year 1846, of the meteorological observations made since 1834, at the Ordnance Survey Office, at Mountjoy, near Dublin,—and also towards the publication, recommended by the British Association in 1849, and sanctioned by the Treasury in February, 1850, of the principal geodetic results of the Trigonometrical Survey of the British Islands,—the Council requested two of their members, Lord Wrottesley and Sir Charles Lemon, who are also members of the Legislature, to make the necessary inquiries; and the Council are in consequence enabled to state on the authority of replies received from the Inspector-General of Fortifications:—1st. In respect to the Mountjoy Observations, that "the whole of the observations have been copied into tables for publication, and the monthly means taken, and that considerable progress has been made in abstracting the results; and that the Director of the Ordnance Survey will shortly have to make application to the Board of Ordnance to obtain the necessary sanction for the Stationery Office, in Dublin, to commence the printing of this work" And 2nd, in respect to

the British Arc of the Meridian, that "during the past season (1850) the large theodolites have been on two stations in Scotland that required additional observations to be made from them, so as to perfect the chain of triangulation; and other observations are now being made at two other stations, at which those made in 1809 and 1841, under unfavourable circumstances, have proved to be insufficient; but the Director of the Survey is in great hopes that no others will require to be done. The Zenith Sector has also been employed during the past season in extending to its utmost limits the second largest Arc of the Meridian in the British Islands, viz. from North Rona Island to St. Agnes in the Scilly Islands, and in establishing, by direct observations, at a station near Peterhead, what had previously been imagined to be the case, that a deflection of the plumb line, to the extent of 8 seconds, existed at Cowhythe Station, near Portsoy in Banffshire, and that in consequence, its resulting latitude must be exceptionable. These observations and others, including those made at 26 stations, are almost entirely printed, and far advanced towards publication. In the office, the reduction and examination of the observations, so as to fit them for publication, has been steadily proceeded with, but the pressure for the Survey, under the Public Health Act, has prevented as much progress being made as could be wished. The Director of the Survey trusts, however, that he shall be enabled to furnish, for communication to the British Association that will probably assemble in 1852, the principal results obtainable from the Geodetic operations in Great Britain and Ireland. The Master-General and Board's Order, of the 30th of March, 1850, also contemplates the publication of the levels in the United Kingdom: this work is also in preparation, and the first volume of it is nearly ready for the press."

IV. Having thus noticed, in the preceding paragraphs of this report, various subjects involving applications to Government, which have been referred by the General Committee to the care of the Council, the Council deem it their duty to bear testimony to the courtesy with which applications on the part of the British Association have been invariably received by the Members of Her Majesty's Government, and to their general readiness to comply with recommendations so made. The recommendation of a Survey of the Southern Nebulæ is the only instance in which there has not been an *immediate* compliance; and even in this exceptional case, the postponement is accompanied by a full admission of the interest of the proposed investigation.

V. The General Committee have directed the Council to consider and report upon such further steps as may appear desirable to be taken in reference to the Committee of Members of the Association, also Members of the Legislature, appointed to watch over the interests of Science, and to inspect the various measures which might from time to time be introduced into Parliament likely to affect such interest. By the original constitution of that Committee, as appointed at Birmingham in 1849, it comprised all the Members of the Association who were also Members of the Legislature, and it has been found practically that the number of the Members of the Committee so constituted, is too large for combined or permanent action. The Council therefore recommend to the General Committee at Ipswich, to appoint a Committee, consisting of a limited number of Members of the Legislature, who are also Members of the Association, for the purposes contemplated in the original appointment of the Committee on the 19th of September, 1849; and they further suggest that the following noblemen and gentlemen, being twelve in number, of whom six are Members of the

House of Peers, and six of the House of Commons, be requested to form the Committee, viz.—

The Lord Wrottesley.	Sir Philip Egerton, Bart.
The Earl of Rosse.	Sir Charles Lemon, Bart.
The Duke of Argyll.	Sir R. H. Inglis, Bart.
The Earl Cathcart.	Sir John Johnstone, Bart.
The Earl of Enniskillen.	James Heywood, Esq.
The Earl of Harrowby.	J. H. Vivian, Esq.

VI. A Memorial presented to the meeting at Edinburgh, by M. Kupffer, Corresponding Member of the British Association, entitled "Projet d'une Association pour l'Avancement des Sciences Météorologiques," having been referred by the General Committee to the Officers of the Association, the following reply, prepared by the officers, was approved by the Council, and transmitted, by their direction, to M. Kupffer:—

"London, November 29, 1850.

"Sir,—We are directed by the Council of the British Association to acquaint you that your Memorial, entitled 'Projet d'une Association pour l'Avancement des Sciences Météorologiques,' was duly received, and was laid before the General Committee of the Association at their meeting at Edinburgh. The General Committee, however, feeling their inability to decide immediately on a subject of such extent and importance, directed that the Memorial should be printed for the perusal of the Officers of the Association; and, the officers having thus had opportunity of maturely considering the proposal, and having stated to the Council their views upon it, we are directed by the Council to transmit to you their reply, as follows:—

"'The Council are very strongly impressed with the advantages that must result to the science of Meteorology from the prosecution of regular series of observations conducted on a uniform plan, and extending over a considerable portion of Europe and perhaps of Asia. But the Council perceive also that there are at present serious difficulties in the way of carrying out such a plan. It would, as they think, be difficult at any time to nominate for each of the associated countries a Director possessing the requisite zeal and knowledge and leisure; and the periodical meetings of the Directors would be found to be a source of extreme trouble. On the other hand, it would be difficult to induce the various Directors to agree to defer to the judgement of one Arch-Director. At the present time, when the construction of some of the most important meteorological instruments is a subject of active criticism, it would not be easy to establish uniformity of plan. And it would be difficult to provide the funds which establishments of such extent must require.

"'These considerations, in the opinion of the Council, are sufficient to show that the establishment of the proposed Association must at all times be difficult. But they cannot omit to add that in the present disturbed state of Europe the difficulty must be greatly increased. It is known to members of the Council that state necessities, produced by convulsions which are not yet allayed, have already caused the withdrawal of some grants for scientific purposes of which the amount is small in comparison with those which would be required for the proposed Association, and the Council therefore have not the least hope that the Association could be established in an effective form for some considerable time.

"'The Council are aware that in France, the construction of some of the

principal meteorological instruments, and the investigation of the theories applying to their use, have undergone careful experimental investigation; that these investigations are now in the course of being repeated and extended in England, and that they are probably carried on also in other countries. For the successful establishment therefore of such an Association, the Council are disposed to look to some future time, when the construction of instruments shall be better understood, when the purposes of observation shall be more distinctly fixed, and when the political condition of Europe shall be more favourable to the co-operation of nations for a scientific object.

"'We have the honour, &c.

"'Edward Sabine
"'J. Forbes Royle } General Secretaries.'"

"'*A Monsieur A. T. Kupffer.*'"

VII. The Council have been informed by a Committee of the inhabitants of Belfast, appointed in 1848 to make arrangements for inviting the British Association to hold an early meeting in that town, that all the public bodies of Belfast, and the Grand Jury of the County of Antrim, are prepared to renew their invitation for the year 1852, and that a deputation will attend at Ipswich for that purpose.

VIII. The Council are glad to have it in their power to report to the General Committee, and through them to the Members of the Association at large, that the conduct of the experimental researches proceeding at the Physical Observatory of the British Association at Kew, has received the most assiduous and unremitting attention from the Committee of Superintendence, continued by the General Committee at Edinburgh, and re-appointed by the Council at their first meeting in November last; and that the number, variety, and importance of the researches in progress and in preparation, are such as to give full promise of the Kew Observatory becoming a most valuable establishment for the advancement of the Physical Sciences. In such a brief notice of these researches as appears most suitable for this Report, it is the purpose of the Council to indicate the objects rather than to explain or discuss them, for which the meetings of the Sections will afford more appropriate occasions; and in this view the Council have requested that the Members of the Kew Committee who have attended to particular branches of the experiments in progress, will prepare Reports concerning them specially designed for communication to the Sections, in addition to the Report annually presented by Mr. Ronalds, whose valuable and gratuitous services are still continued. In reference to the instruction of the General Committee to the Council at the Edinburgh Meeting, to communicate with the Government, if necessary, respecting the possibility of relieving the Association from the expense of maintaining the establishment at Kew, the Council have not thought it desirable to make such direct application to the Government, but they have to report that considerable additions have been obtained to the pecuniary resources by which the experimental researches are carried on—1st, from the Donation Fund of the Royal Society, and 2nd, from the Government Grant, placed annually at the disposal of the President and Council of the Royal Society, the particulars of which will now be stated.

1. £100 was allotted from the Government Grant of 1850 for the purchase of magnetical and meteorological instruments of a new construction, for a trial of their merits at the Kew Observatory. This sum has been expended—1st, in the construction of a Vertical Force Magnetograph, for the self-registry on Mr. Ronalds's principle of the variations of the Vertical Force;

2nd, in the purchase and improvement of M. Regnault's modification of Daniell's Hygrometer; and, 3rd, in the purchase of a Standard Thermometer, in which the accuracy of the temperatures indicated by all the divisions of the scale has been examined, and is guaranteed by the well-known skill and care of M. Regnault; which instrument it is intended to employ in the verification of thermometers made by artists in this country.

2. The difficulty in respect to funds for the completion of Mr. Ronalds's instruments for the self-registry of magnetical observations having thus been surmounted, the Royal Society have granted to Mr. Ronalds, from the donation fund at their disposal, £100, to be applied in an experimental trial of those instruments for a period of six months; during which they are to be worked precisely as in an Observatory, and a minute account kept of every item of expense incurred in carrying on the self-registry for that period. This experimental trial is now in progress, having been commenced in April.

3. £150 has been allotted from the Government Grant of 1851, for the construction and verification of standard Meteorological Instruments at Kew, and for the purchase of apparatus required for that purpose. The notification of this grant has been but just received, but, by its aid, M. Regnault's apparatus for calibrating and graduating Thermometer Tubes has already been procured, and steps have been taken for the examination of the different kinds of glass which are likely to be best adapted for thermometers.

4. £175 has been allotted from the Government Grant of 1851, to Professor Stokes, of Cambridge, for Experiments to be made at Kew, to determine the Index of Friction in different Gases. The notification of this grant is also very recent; but apparatus has been ordered, and the experiments will be commenced forthwith.

With this assistance, the expenditure for the maintenance of the Observatory has not exceeded the sum placed at the disposal of the Council for that purpose; and there are no debts.

In the various experimental researches which have been thus enumerated, conducted as they severally are by Members of the British Association, whose services are gratuitous, the Council are glad to be able to report, on the authority of the Kew Committee, that great advantage is derived from the zeal, assiduity and intelligence with which they are assisted by Mr. Welsh, late Assistant in Sir Thomas Brisbane's Observatory at Makerstoun, whose services the Council have engaged at a salary of £100 a year (with residence), payable out of the £300 placed at their disposal by the General Committee, but not guaranteed of course beyond the current year, which terminates with the Ipswich Meeting.

In concluding this notice of the present state and prospects of the Kew Observatory, the Council take occasion to remark, that the liberality with which the British Association has nursed the infancy of an establishment, novel in its purposes, and not therefore perhaps duly appreciated by all at first, has already produced contributions towards its objects from other sources, and which in the present year considerably exceed the sum granted by the Association itself; and taking into account that the institution works well under its present arrangements and on its present footing, and believing that its continuance will be conducive alike to the advancement of science and to the credit of the British Association, they recommend that the grant of £300 to the Kew Observatory should be continued for the next year.

Recommendations adopted by the General Committee at the Ipswich Meeting in July 1851.

Involving Grants of Money.

The Establishment at Kew Observatory £300.

That Professor J. D. Forbes be requested to continue a Series of Experiments, for the purpose of testing the results of the Mathematical Theory of Heat; that Professor Kelland be requested to co-operate with him; and that £50 be placed at the disposal of Prof. Forbes for the purpose.

That Professor E. Forbes and Professor Bell be requested to continue their assistance to Dr. Thomas Williams in his researches on the Annelida, with £10 at their disposal.

That the Committee on the Vitality of Seeds be requested to continue their attention to that subject, with £6 at their disposal.

That a Committee, consisting of Mr. R. Hunt, Dr. G. Wilson, and Dr. Gladstone, be requested to investigate the influence of the solar radiations on chemical combinations, electrical phænomena, and the vital powers of plants growing under different atmospheric conditions, with £20 at their disposal.

That Lord Monteagle, Sir J. Boileau, Mr. G. R. Porter, Mr. J. Fletcher, Dr. Stark, and Professor Hancock, be requested to prepare a Report on the Census of the United Kingdom; and that the sum of £20 be placed at their disposal for the purpose.

That Mr. W. Fairbairn, C.E., be requested to make a series of Experiments on the tensile strength of Wrought Iron Boiler-Plates at various temperatures; and that the sum of £20 be placed at his disposal for the purpose.

That Professor Ramsay be requested to prepare a large Geological Map of Great Britain and Ireland for the use of the Geological Section during the Meetings of the Association, with £15 at his disposal for the purpose.

Involving Application to Government or Public Institutions, or Members of the Legislature.

That the Parliamentary Committee of the British Association do consist of Thirteen Members.

That the following Noblemen and Gentlemen be requested to constitute the Committee:—The Lord Wrottesley, the Duke of Argyll, the Earl of Enniskillen, the Earl of Harrowby, the Earl Cathcart, the Earl of Rosse, the Lord Bishop of Oxford, Sir Philip Egerton, Bart., Sir Charles Lemon, Bart., Sir Robert H. Inglis, Bart., Sir J. V. B. Johnstone, Bart., J. H. Vivian, Esq., James Heywood, Esq.

That in case of vacancies occurring in the Committee, the General Committee shall, at their next ensuing Meeting, proceed to fill up such vacancies from Members of the British Association who are Members of either House of Parliament, and who have either communicated to a Philosophical Society any paper which has been printed in its Transactions, or have advanced the interests of Science.

That the Parliamentary Committee shall have power to appoint Members of the Legislature who are Members of the British Association qualified as above mentioned, to act *ad interim* till such vacancies be supplied.

That the Parliamentary Committee have the power to call in the aid of any Members of the Legislature on any occasion on which they may deem such assistance expedient.

That the Rev. Dr. Whewell, the Earl of Rosse, Sir John F. W. Herschel, and the Astronomer Royal, be a Committee to apply to Her Majesty's Government with a view of inducing them to send an expedition consisting of one

or two small vessels to trace the course of the Tides in the Atlantic, with an especial view to ascertain the points of divergence and of convergence of the tidal wave on the West Coast of Africa and on the East Coast of South America, the progress of the diurnal inequality and of the semi-mensual inequality on those coasts, the relation of the tides at islands remote from the coasts with the tides on the coasts, and the direction and degree of the streams of ebb and flow in the various regions of the Ocean.

The Committee having had brought to their notice the zoological and anatomical investigations made by Mr. T. H. Huxley, Assistant Surgeon of Her Majesty's Ship Rattlesnake, during the Surveying Voyages conducted by the late Captain Owen Stanley on the Coasts of Australia and New Guinea, and believing those researches to be of the greatest value and to throw new light on the structure and history of tribes of animals hitherto imperfectly understood,—

Resolved,—That application be made to Her Majesty's Government for a grant towards their publication, since without such aid the materials collected and researches made during the Expedition in question cannot be placed before the public.

The Committee, having had brought to their notice the extent and importance of the Botanical Collections and observations made by Dr. J. D. Hooker and Dr. T. Thomson in the Himalaya Mountains and other parts of India where they have lately been employed on Botanical missions under Her Majesty's Government and the East India Company, and to which special attention was directed in the opening address of the President of the Association; and having further learned that other valuable collections have lately been made in the Himalaya by Major Madden, Captain R. Strachey and Mr. J. E. Winterbottom, which are now available; also taking into consideration the amount of unpublished materials from the same country still deposited in our Museums; and knowing that Drs. Hooker and Thomson, who are both accomplished Botanists, are willing to undertake the arrangement of all these materials with the intention of combining them with former publications into a general Indian Flora,—

Resolved,—That Her Majesty's Government and the Court of Directors of the East India Company be requested to give the aid essential for the speedy publication of such a work, which they conceive would be a most valuable addition to our Botanical knowledge, but which is manifestly beyond the means of private individuals. They would further add, that it appears to them most important that immediate steps should be taken in this matter while the great mass of the Collections is still uninjured by time, and while their description can be undertaken by the very persons who made them, —a combination of advantages which must soon be lost.

The Committee of the British Association having had brought before them the explorations of Captain Richard Strachey of the Bengal Engineers in the Himalaya Mountains and Thibet, and the desirableness of the speedy publication of these researches,—

Resolved,—That a request be made to the Court of Directors of the East India Company to afford to Captain Strachey such aid as will enable him to lay them before the public with such illustrations in Maps and Plates as are essential for their proper elucidation.

Reports requested.

Rev. Dr. Robinson.—On the Progress of Captive Balloon Experiments.

Sir W. S. Harris.—On the Progress of the Reduction of 12 years' Anemometrical Observations placed in his hands for that purpose.

Prof. W. Thomson.—On Electrical Theories.

Professor Powell.—On Radiant Heat.

Lieut.-Col. Sabine.—Results of Magnetic Cooperation and Magnetic Surveys.

Committee (Prof. Daubeny, Prof. Graham, Sir R. Kane, Prof. Gregory and Prof. Williamson).—On Nomenclature of Organic Substances.

W. Thompson, Esq.—On Natural History of Ireland.

Committee of Prof. Henslow, W. Thompson, Esq., Sir W. Jardine, Prof. Phillips, C. C. Babington, Esq., A. Strickland, Esq., H. E. Strickland, Esq. Prof. E. Forbes, F. W. Johnson, Esq., Prof. Ansted, Prof. Owen, Dr. J. D. Hooker, J. S. Bowerbank, Esq., Rev. M. J. Berkeley, Prof. Harvey, J. E. Gray, Esq., J. Alder, Esq., Dr. G. Johnston.—On Typical Arrangements in Provincial Museums of Natural History.

W. Fairbairn, Esq.—On Mechanical Properties of Metals as derived from repeated meltings, exhibiting the maximum point of strength and the causes of deterioration.

Sir D. Brewster was requested to publish his Experiments on the Spectrum.

Printing of Communications.

That Mr. Drew's Tables of Mean Results of Meteorological Observations at Southampton be printed at length in the Volume of the Association.

That M. Dumas be requested to favour the Association with a written statement of his verbal remarks "On Atomic Volume and Atomic Weight, with considerations on the probability that certain bodies now considered as Elementary may be decomposed," for the purpose of being printed in full in the Report for the present year.

That Professor Daubeny be requested to furnish a copy of his paper "On the Chemical Nomenclature of Organic Substances," to be printed in the Volume of Reports, and that the Committee appointed on this subject be furnished as early as possible with 100 copies of such communication for circulation amongst those chemists most likely to afford assistance.

Miscellaneous.

That the following gentlemen be requested to act as a Sub-committee to consider and report to the Council within two months on the propriety of printing, in the next Volume as a Report, Dr. Donaldson's paper "On Ethnographical Classification:"—The Chevalier Bunsen, Dr. Latham, Col. Rawlinson, Rev. Mr. Rigaud and Mr. Cull.

That Mr. Cull be added to the Committee to print Ethnological queries, in the place of Vice-Admiral Malcolm, deceased.

N.B. The following Recommendations from the Committee of Section C (Geology), did not reach the Committee of Recommendations in time to be reported on, but have been since acted on by direction of the Council:—

That a Committee be appointed to take into consideration and report upon the exact position, number and nature of the phosphatic beds of the Crag, and to connect this subject with that of mineral manures generally with reference to their scientific and œconomic value; and further to investigate the geological conditions under which the so-called 'Coprolites' and other drifted Organic and Inorganic bodies occur in the Red Crag, and the probable sources from which these bodies have been respectively derived. The

Committee to consist of Prof. Henslow, Mr. Searles Wood and Mr. Long, with power to add to their number.

That Mr. Searles Wood be requested to prepare for the next Meeting of the Association, a Report of the observed distribution of the specific forms of Vertebrata and Invertebrata in the supracretaceous deposits in the vicinity of Ipswich.

That Mr. Logan's paper on the Geology of Canada be printed in full in the next Volume of the Reports of the Association.

Synopsis of Grants of Money appropriated to Scientific Objects by the General Committee at the Ipswich Meeting in July 1851, *with the Name of the Member, who alone, or as the First of a Committee, is entitled to draw for the Money.*

	£	s.	d.
Kew Observatory.			
At the disposal of the Council for defraying Expenses........	300	0	0
Mathematical and Physical Science.			
FORBES, Prof. J. D.—Experiments for the purpose of testing the results of the Mathematical Theory of Heat	50	0	0
Chemical Science.			
HUNT, Mr. R.—Influence of the Solar Radiations or Chemical Combinations, Electrical Phænomena, and the Vital Powers of Plants growing under different atmospheric conditions..	20	0	0
Geology.			
RAMSAY, Prof.—Geological Map of Great Britain and Ireland, for the use of the Geological Section during the Meetings of the Association..................................	15	0	0
Natural History.			
FORBES, Prof. E.—Researches on Annelida.................	10	0	0
STRICKLAND, H. E.—Vitality of Seeds.....................	6	0	0
Statistics.			
MONTEAGLE, LORD—Report on the Census of the United Kingdom..	20	0	0
Mechanical Science.			
FAIRBAIRN, Mr. W. C.E.—Experiments on the Tensile Strength of Wrought Iron Boiler plates at various temperatures ..	20	0	0
Grants........	£441	0	0

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837.			
Tide Discussions......	284	1	0
Chemical Constants ..	24	13	6
Lunar Nutation	70	0	0
Observations on Waves.	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature .	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments....	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838.			
Tide Discussions......	29	0	0
British Fossil Fishes ..	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (strength of) .	60	0	0
Animal and Vegetable Substances (preservation of)	19	1	10
Carried forward	£308	1	10

	£	s.	d.
Brought forward	308	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee ..	50	0	0
Heart Experiments....	5	3	0
Land and Sea Level ..	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth ..	63	10	0
Mechanism of Waves ..	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature .	21	11	0
Vitrification Experiments	9	4	7
Cast Iron Experiments.	100	0	0
Railway Constants	28	7	2
Land and Sea Level ..	274	1	4
Steam-Vessels' Engines.	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air......	16	1	0
Cast and Wrought Iron.	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie ..	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics......	50	0	0
	£1595	11	0

	£	s.	d.
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments....	18	19	0
Lungs Experiments ..	8	13	0
Tide Discussions......	50	0	0
Land and Sea Level ..	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air......	15	15	0
Water on Iron.........	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population ..	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phænomena........	40	0	0
Meteorological Observations at Plymouth ..	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves.	30	0	0
Meteorology and Subterranean Temperature .	8	8	0
Actinometers	10	0	0
Earthquake Shocks ..	17	7	0
Acrid Poisons........	6	0	0
Veins and Absorbents..	3	0	0
Mud in Rivers........	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers..	6	18	6
Stars (Histoire Céleste).	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of) ..	40	0	0
Water on Iron........	50	0	0
Meteorological Observations at Inverness ..	20	0	0
Meteorological Observations (reduction of)..	25	0	0
Carried forward	£539	10	8

	£	s.	d.
Brought forward	539	10	8
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth ..	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith........	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men........	5	0	0
Radiate Animals......	2	0	0
	£1235	10	11
1842.			
Dynamometric Instruments	113	11	2
Anoplura Britanniæ ..	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education..	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (British Association Catalogue of) ..	110	0	0
Railway Sections......	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels.......	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth..	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind........	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Carried forward	£1442	8	8

	£	s.	d.
Brought forward	1442	8	8
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth ..	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth ..	20	0	0
Reduction of Meteorological Observations ..	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness ..	56	12	2
Magnetic Co-operation .	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways........	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections....	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Carried forward	£977	6	7

	£	s.	d.
Brought forward	977	6	7
Uncovering Lower Red Sandstone near Manchester............	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological operations of Medicinal Agents	20	0	0
Vital Statistics.........	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Observations on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator ..	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness..........	12	0	0
Completing Observations at Plymouth........	35	0	0
Magnetic and Meteorological Co-operation..	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland	100	0	0
Revision of the Nomenclature of Stars.. 1842	2	9	6
Maintaining the Establishment in Kew Observatory..........	117	17	3
Instruments for Kew Observatory..........	56	7	3
Carried forward	£384	2	4

	£	s.	d.
Brought forward	384	2	4
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes, 1842	23	11	10
Researches into the Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical distributions of Marine Zoology 1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds..1842	8	7	3
Researches on Exotic Anoplura	15	0	0
Experiments on the Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument, 1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Carried forward	£399	10	1
Brought forward	399	10	1
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
Experiments on the Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura..1843	10	0	0
Vitality of Seeds..1843	2	0	7
Vitality of Seeds..1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Registration of Earthquake Shocks ..1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars, 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1839	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Experiments on the Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds..1844	2	15	10
Vitality of Seeds..1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Carried forward	£605	15	10

	£	s.	d.
Brought forward	605	15	10
Marine Zoology of Britain	10	0	0
Exotic Anoplura ... 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Researches on Atmospheric Waves	3	3	3
Captive Balloons ... 1844	8	19	8
Varieties of the Human Race ... 1844	7	6	3
Statistics of Sickness and Mortality at York	12	0	0
	£685	16	0
1847.			
Computation of the Gaussian Constants for 1839	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Researches on Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4
1848.			
Maintaining the Establishment at Kew Observatory	171	15	11
Researches on Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8
1849.			
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phænomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	£159	19	6
1850.			
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phænomena	15	0	0
Meteorological Instrustrument, Azores	25	0	0
	£345	18	0
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Experiments on the Theory of Heat	20	1	1
Periodical Phænomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

Extracts from Resolutions of the General Committee.

Committees and individuals, to whom grants of money for scientific purposes have been entrusted, are required to present to each following meeting of the Association a Report of the progress which has been made; with a

statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of pecuniary aid for scientific purposes from the funds of the Association expire at the ensuing meeting, unless it shall appear by a Report that the Recommendations have been acted on, or a continuation of them be ordered by the General Committee.

In each Committee, the Member first named is the person entitled to call on the Treasurer, John Taylor, Esq., 6 Queen Street Place, Upper Thames Street, London, for such portion of the sum granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the Members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named shall be deemed to include, as a part of the amount, the specified balance which may remain unpaid on the former grant for the same object.

General Meetings (in the Corn Exchange).

On Wednesday, July 2nd, at 8 P.M., the late President, Sir David Brewster, K.H., D.C.L., LL.D., F.R.S., V.P.R.S.E., resigned his Office to George Biddell Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal, who took the Chair at the General Meeting, and delivered an Address, for which see p. xxxix.

On Thursday, July 3rd, a Microscopic Soirée took place from 8 to 10 P.M.

On Friday, July 4th, at 8 P.M., Richard Owen, Esq., F.R.S., Professor of Anatomy in the College of Surgeons, London, delivered a Discourse on the distinction between Plants and Animals, and their Changes of Form.

On Monday, July 7th, at 8 P.M., the President, G. B. Airy, Esq., F.R.S., Astronomer Royal, delivered a Discourse on the Total Solar Eclipse of July 28, 1851.

On Tuesday Evening, July 8th, at 8 P.M., the concluding General Meeting of the Association was held in the Theatre of the Mechanics' Institute, when the Proceedings of the General Committee, and the grants of Money for scientific purposes were explained to the Members.

The Meeting was then adjourned to Belfast in 1852*.

* The Meeting is appointed to take Place on Wednesday, the 1st of September, 1852.

ADDRESS

BY

GEORGE BIDDELL AIRY,

M.A., D.C.L., F.R.S., &c., Astronomer Royal.

Gentlemen of the British Association,—I cannot take the Chair at this meeting, even after the cordial invitation of your General Committee, without a painful feeling, not only of the general responsibilities of the position, but also of the difficulties which are peculiar to myself. Engaged officially in a science the pursuit of which leaves little leisure for the employment of time and little freedom for the range of thought, I follow a philosopher whose investigations have been dispersed through almost every branch of physical science. My own attendance at the meetings of the Association has been limited, and my acquaintance with its forms of proceedings small: and I feel the disadvantage of succeeding in this Chair one who may justly be regarded as the Founder of the Association. Still, I have judged it incumbent on me to accede to the honourable invitation which was pressed upon me; and to endeavour, by attention to the business of the meeting, to render such services to the Association as it may be in my power to offer, and such as may in some degree compensate for the partial disabilities to which I have alluded. We meet, not as a body of accomplished philosophers, but as a number of individuals, each of us anxious for the advance of science, each of us sensible that he cannot urge every part of it by his own personal contributions, but each of us desirous of assisting it in any direction in which his knowledge or his talents, whether scientific or administrative, enable him to give efficient aid. Permit me, on this occasion, to meet you on the same terms; and let me offer you my assurance that,

though the title of President may not be connected with the highest talent or the most universal knowledge in this great assembly, you shall nevertheless find that it is not attached to the least industrious or the least ardent of its members.

It is required by the custom of the Association that at the opening of each of its meetings the President should lay before the Association such remarks on the state of those sciences which are included in its objects, and especially such an account of their progress in the past year, as he may judge suitable to the time and serviceable for the guidance of the Association in the conduct of the commencing meeting. I find it impossible to give even the most summary statement of this nature without alluding to the acts of the Association, and to the establishment or modification of other institutions connected with Science or Art; and I propose, therefore, to submit to you the mingled history of the progress of Science,—of the efforts, the successes, and the failures of the Association in reference to it,—and of the state of some other institutions. In some departments I fear that my account will be extremely defective: I trust, however, that those of my hearers who may be sufficiently interested in this Address to notice its omissions will not fail to use the opportunities of various kinds which the discussions in the Sectional meetings afford for supplying them.

Commencing, then, with the subject which stands first in the Reports of the Association, and on which the funds of the Association have been most generously expended and its influence very energetically employed, I remark that the progress of Astronomy in the last year has been very great. The Earl of Rosse has been much engaged in experiments on the best methods of supporting and using his large mirrors. The construction adopted some time since is still retained; namely, a system of levers distributing their pressures uniformly over eighty-one points, each pressure being transmitted through a small ball which permits to the mirror perfect freedom of slipping in its own plane, so as to take proper bearing in the chain or hoop which supports it edgeways. To Lord Rosse's critical eye the effect even of this mounting, though greatly superior to that of any preceding, is not quite perfect. In the progress of the experiments, some singular results have been obtained as to the set which a metal so hard as Lord Rosse's composition may receive from an unequal pressure of very short duration. A surface of silver, I believe, has now been successfully used for the small reflector. Of the character of the discoveries in nebulæ made with this instrument I cannot briefly give any very correct idea. The most remarkable is, the discovery of new instances of spirally-arranged nebulæ: but there are also some striking examples of dark holes in bright matter, dark clefts in bright rays,

and resolvability of apparently nebulous matter into stars. I do not deny the importance of the last observation; but as it might be predicted beforehand that the increase in the dimensions of telescopes would lead to more extensive resolution of nebulæ, I do not hold the inference to be by any means certain that all nebulæ are resolvable. Mr. Lassell exhibited at the last meeting of the Association a plan for supporting his two-feet mirrors without flexure. This plan, slightly modified, has been adopted in use: and I am assured that the improvement in what before seemed almost perfect definition is very great. The removal of the vexatious fiscal interferences with the manufacture of glass, and the enterprise with which Mr. Chance as manufacturer and Mr. Simms and Mr. Ross as opticians, have taken up the construction of large object-glasses, promise to lead to the most gratifying results. Already Mr. Simms has partially tested object-glasses of 13 inches aperture; and one of 16 inches is waiting not for the flint but for the crown lens. Mr. Ross, it is understood, has ground an object-glass of 2 feet aperture; but it has not been tested. The facility of procuring large object-glasses will undoubtedly lead to the extensive construction of graduated instruments on a larger scale than before; and it is in this view that I contemplate as a matter of no small importance the erection (this year) of the large transit-circle at the Royal Observatory at Greenwich. It is known to many members of the Association that this instrument was constructed in this town, by Messrs. Ransomes and May; and for the admirable proportions of its various parts, for the firmness of fitting of the few portions of which it is composed, and for the accuracy of the external forms of pivots, &c., it may well be considered as one of the finest specimens of engineering that has ever been produced. As an example of an excellent mechanical structure carrying a large object-glass, I think it probable that this Greenwich transit-circle may have a great influence on the construction of future instruments. I had hoped to be able by this time to report to the Association on the American method of recording transits, by a puncture or dot produced by a galvanic agency whose circuit is closed by a touch of the observer's finger,—and especially on its fitness for the wants of a really active observatory; but the delays of construction have prevented me from doing so. Shortly before the last meeting of the Association, the President for the time (Dr. Robinson) transmitted to the Government, on the part of the Association, a general request that a large reflecting telescope might be sent to some of the British possessions in the southern hemisphere, for the purpose of observing the southern nebulæ; and shortly after that meeting an answer was received from the Lords of the Treasury, to the effect that their Lordships entirely recognised the importance of the object, but that there appeared to be prac-

tical difficulties in the immediate execution of the design. I cannot doubt that when a more explicit plan has been formed, another representation will be accompanied with the same success which has attended every application made by the Association for aid in a carefully arranged design. It will be interesting to the Association to learn that the continuation of the observations on α Centauri at the Cape of Good Hope has fully confirmed the result first obtained,—namely, that the parallax of that star exceeds nine-tenths of a second, or that its distance from the sun is about twenty billions of miles. So far as we have the means of judging, this star is our nearest neighbour in the sidereal spaces. The attention of foreign astronomers is still directed to the irregularities in the proper motions of stars, and the opinion seems to be gaining ground that many of them are accompanied by non-luminous companions. In our own solar system, the most remarkable discovery is that (made independently, though on different days, in America and in England) of a dusky ring interior to the well-known rings of Saturn. It now appears that it had been seen several years before ; but it then attracted no attention. How such a ring is composed, and how sustained, are questions upon which perhaps the physical astronomer may long employ himself. But the discovery for which the year will be most frequently cited is that of three additional planets, included in the same planetary space—between Mars and Jupiter—in which eleven others had been previously found. The last of these (Irene) discovered by Mr. Hind, observer in the private observatory of Mr. Bishop, forms the fourth of his list,—and makes his number the greatest that any one man has ever discovered. Some time since, a grant was made by the British Government for the perfection of the Lunar Theory and Lunar Tables on which Prof. Hansen, of Gotha, had been engaged, but whose progress was stopped by the interruption of funds in consequence of the unhappy Schleswig-Holstein war. I understand, that with the aid of this grant, equally honourable to the British Government and to the foreign philosopher, the work is now rapidly advancing. I have reason to believe that the theories of Uranus and Neptune are now undergoing careful revision; and I trust that one of the elements most urgently required, namely, the mass of Neptune, will be supplied from observations of Neptune's satellite made with the large telescopes to which I have alluded.

At the Edinburgh meeting, the attention of the Mathematical and Physical Section was called by M. O. Struve (there present) to the total eclipse of the sun which is to occur on the 28th day of the present month ; and the General Committee appointed a Committee of members of the Association to draw up Suggestions for the observation of the eclipse. These Suggestions have been extensively distributed both at home and abroad : and I am happy

to announce one of the results. After consideration of the singular appearances observed in the eclipse of 1842, it was determined by the Committee to recommend (among other things) that observing stations should be selected, if possible, in triplets: the three stations of each triplet having relation to the north boundary, the centre, and the south boundary of the shadow. The Russian Government has fully adopted this suggestion; and has actually equipped six triplets, including in all eighteen stations, with observers and instruments for the observation of the eclipse. Russian officers in the Sea of Azov and the Black Sea will also observe it. Since the issue of the Suggestions, the observations made last year on an eclipse visible at Honolulu in the Sandwich Islands have been received; and they make us, if possible, still more desirous that the spirit of the Suggestions should be complied with, as far as possible. There is only one subject of regret connected with this remarkable eclipse,—namely, that it will deprive us of the assistance of several astronomers who would undoubtedly have joined this meeting but for the necessity of being ready, at definite points, for the observation of the phænomena.

Among subjects related in some measure to astronomy, I may first allude to M. Foucault's experiment on the rotation of the plane of a simple pendulum's vibration; an experiment which has excited very great attention both in France and in England, as visibly proving, if proof were necessary, the rotation of the earth. It is certain that M. Foucault's theory is correct, but it is also certain that careful adjustments, or measures of defect of adjustment, are necessary to justify the deduction of any valid inference. For want of these, the experiment has sometimes failed. The Council of the Association have long regretted the very great delay which has occurred in the publication of the geodetic results of our great National Survey; and they were prepared some time since to represent strongly to the Government the expediency of taking immediate steps for completing the few calculations which yet remained to be made, and for publishing the whole in a form which should be available for discussions of the figure of the earth. On communicating with the Royal Society they learned that that body had made an urgent recommendation to the same tenor, and that in consequence Government had consented to place on the Estimates a sum of money expressly for the purpose of completing and publishing the scientific portions of the survey. I have received official information that this work is now in active progress; and I cannot but remark on it as a striking instance of how much may be sometimes effected for the purposes of science by simply completing what is nearly complete. The great Swedish and Russian Arc of Meridian, from the North Cape to the Danube, is so far advanced that its completion is expected in the present year.

At the last meeting of the Association, a Committee was appointed expressly to urge on the Government, what had long excited the attention of the Association, the defective state of the Survey as regards Scotland. I am happy in stating that there is strong reason to hope that a large sum will in future be appropriated to the Scotch Survey. Whether this be considered as giving to the country the advantages of an accurate territorial map or as aiding in a most peculiar degree in geological inquiries,—in either point of view it is a matter of interest to the Association, and it will be a matter of satisfaction to them that, mainly through their representation, this object has been attained.

The next subject to which the influence of the Association was energetically directed is, Terrestrial Magnetism; with which Meteorology has usually been associated. Although the active employment of several of the Colonial Magnetic and Meteorological Observatories has terminated (those only of Toronto, Hobartown, Cape of Good Hope, Madras and Bombay being retained, and only in partial activity), the work connected with them has not yet ceased. Much has yet to be done in the printing and discussion of the observations:—a work going on under the care of Col. Sabine. In tacit association with the representative of the Government, the agents of the Association are employed at the Kew Observatory, under the superintendence of Mr. Ronalds, in devising or examining new instruments. The Daguerreotype method of self-registration (which is perhaps liable to this objection, that the original records are destroyed) has been extended to the vertical-force instrument. Apparatus has been arranged for the graduation of original thermometers—a subject to which the attention of M. Regnault and Mr. Sheepshanks had been advantageously directed. And, with the assistance of a portion of the sum placed by the Government at the disposal of the Royal Society (to which I shall hereafter refer), it is hoped by the officers of the Association that the Kew Observatory will be made really efficient for the testing of new instruments. Dr. Robinson's very instructive account of his new anemometer has lately been received: this instrument, however, has not yet been used in many places. Among the immediate deductions from magnetic observations, I may specially mention Col. Sabine's remarks on the periodical laws discoverable in disturbances apparently of the most irregular kind, and M. Kämtz's corrections of the Gaussian constants. Among the more distant results, there is nothing comparable to the experimental inquiries into the magnetic properties of oxygen, and especially into the variation of its power, made by Messrs. Faraday and Becquerel,—and the application of these results to the explanation of the phænomena, in almost all their varied forms, of so-called terrestrial magnetism. It is to the former of these philosophers that this great step in the explanation of obscure

natural phænomena by inference from delicate experiments, is mainly or entirely due. Much, of course, remains to be done, before we can pronounce accurately how far this principle enables us to account, without reference to any other cause, for the regular changes, as well as for the capricious disturbances, in ordinary magnetism. I ought not to omit stating that such general explanation had long ago been suggested in a very remarkable paper by Mr. Christie; but the experiments actually applying to the magnetic properties of oxygen were unknown, and perhaps impossible, at that time. In the science of abstract magnetism, the distinction between paramagnetic and diamagnetic substances has been thoroughly worked out by Mr. Faraday, and is now received as one of the most remarkable laws of nature. In the related subject of Galvanism, although much of detailed law has been established by the labours of the same great man and of others, it is difficult to fix upon any new law of general character. Experiments made in America seem to establish that the velocity of the galvanic current in iron wires of a certain size does not exceed fifteen or eighteen thousand miles per second: a much greater speed, however, is inferred by M. Fizeau, from the same experiments. The first part of an elaborate mathematical theory of Magnetism, by Prof. Thomson, has been published. In Meteorology, some striking facts have been collected and arranged by Col. Sykes in regard to India, by Messrs. Schlagintweit in regard to the Alps, and by M. Plantamour in the comparison of observations at Geneva and the Great St. Bernard; and some very unexpected facts have been extracted by M. Arago from the observations in a balloon ascent at Paris. The systematic collection of observations of luminous meteors, in Reports by Prof. Powell, printed in the volumes of the Association for the last two years, can scarcely fail to lead to some discovery of the origin and nature of those mysterious bodies. An extensive series of meteorological observations had been made at the Ordnance Survey Office at Mountjoy, near Dublin, and the Association some years since recommended to the Government the early printing of those observations. I have the gratification of stating that considerable progress has now been made in preparing them for the press.

At the last meeting of the Association a project was laid before the General Committee by M. Kupffer, for the formation of a Meteorological Confederation, to be extended over the whole of Europe. A very extensive organization, covering almost the whole Russian Empire, has already been created. The Council, to whom this project was referred, after very careful consideration, deemed it inexpedient to join in the proposed Confederation. They were deterred by various practical difficulties, of which some may perhaps always exist, while others are felt with unusual force at the present time. It was with extreme unwillingness that the Council adopted this reso-

lution, and with the full hope that at some future time a confederation similar to that proposed by M. Kupffer may be firmly established.

Under the auspices of the Board of Ordnance, the officers of the corps of Royal Engineers are making arrangements for the establishment of a uniform system of meteorological observations, of a simple kind, at the principal engineers' stations in every part of the earth. If with these could be combined occasional trustworthy observations at sea, we should probably have the most complete system of Terrestrial Meteorology that we can hope to obtain.

Among systematic observations of less ostentatious character, I cannot omit referring to the daily report of the state of the wind at 9 o'clock every morning, which is supplied by the superintendents of railway stations, over a great portion of the British Isles, and printed in the *Daily News* newspaper.

A new Meteorological Society has been formed, which (I believe) is at least in this respect superior to those which have preceded it—that the instruments used by the various amateur members are strictly comparable: great attention having been given to the adjustments of the instruments, by the Secretary, Mr. Glaisher.

In Optics, two or three investigations of rather important character have, since the last meeting of the Association, attracted public attention. Experimental measures of the velocity of light in air and in water, made by MM. Foucault, Fizeau and Breguet, with apparatus nearly similar to that employed long ago for analogous purposes by Mr. Wheatstone, appear to leave no doubt that the velocity in water is less than that in air,—a most important, and indeed critical, result in regard to theories of light. A remarkable investigation by Prof. Stokes, when compared with experiment, seems to establish that the vibrations constituting polarized light are, as for other reasons was supposed by Fresnel, perpendicular to what is usually called the plane of polarization. Some optical theories which admitted formerly of very imperfect mathematical treatment have been brought under the dominion of analysis by Prof. Stokes's powerful methods of investigation. A curious series of experiments on diffraction has been published by Lord Brougham; but they have at present no bearing on theory, as the theoretical calculations with which they must be confronted appear to be too difficult or too complicated for the present state of pure mathematics. The experiments of Jamin regarding the reflexion of polarized light under peculiar circumstances appear to give support to the theoretical calculations of Cauchy, founded on a molecular hypothesis applied to the undulatory theory. And lastly, some curious experiments by Masson, Jamin, Prevostaye, and Desains, appear to show more fully, what had partially been shown by Prof. Forbes, that radiant heat admits of polarization in all respects similar to that of light.

I hope that we shall receive at this meeting, or shortly, two Reports on

subjects connected in some measure with those which I have just mentioned. One is from Prof. Stokes, 'On our knowledge of the Theory of vibratory Motions of Bodies in general,'—the other from Prof. Willis, 'On Acoustics.'

Our volume of Reports lately published contains a very complete account, by Mr. Hunt, of the present state of our knowledge in regard to the chemical effects of solar radiation.

In the subject of Chemistry, I am not aware that any great step has been made; although there have been numerous small advances in establishing chemical relations and in inventing chemical processes.

The subject of Geology has always excited much interest in this Association. It is a matter of congratulation that the Museum of Economic Geology is now established in a habitation as well as in a form which guarantee its permanent and useful existence. Among subjects bordering on Practical Geology, I may allude to the late inquiries respecting the supply of water from the chalk and Bagshot sand districts as likely to give valuable information. In Speculative Geology, the labours of European as well as American geologists have been continued with their usual ardour, and there are now comparatively few parts of the world which have not been in some degree geologically examined. Far be it from me to pretend to assign with exactness specific discoveries (in observation or in inference) to specific persons; to say precisely what has been done by Sedgwick, what by Murchison, what by Lyell, what by Verneuil,—or even to state with accuracy what discoveries in the aggregate have been made by all. So far, however, as I can gather, the principal step made (not in the last year but in the last few years) has been of this kind. The line between the chalk group and the lowest tertiary or Eocene group has been drawn principally by Sir R. Murchison with great distinctness; and this has been done rather by palæontological criteria than by reasonings from order of superposition, &c. A very great step has been made in the classification of the geology of Asia Minor, with the aid of this new light, by a foreign geologist, M. Tchihatchef, now present. In the course of these investigations, attention has been drawn to the magnitude of the disturbances exhibited in these comparatively modern beds,—and the question has again been raised in the minds of geologists, whether these disturbances can be referred to causes now in action. It would be wrong, however, even in this hasty glance, to omit to notice the discovery of traces of the tortoise in beds so low as the lowest Silurian rocks, affording (apparently) evidence of the existence of this animal at a much earlier time than had usually been ascribed to it. I should be sorry also to make no reference to Sir C. Lyell's calculation of the time of formation of the delta of the Mississippi—or to Prof. J. Forbes's paper on the modern extinct volcanos of the

Vivarais. I may refer with satisfaction to Mr. Mallet's elaborate 'First Report on Earthquake Phænomena' (lately published in our annual volume), —shortly to be followed, I trust, by a second; and I may also remind my hearers that the Association have supplied funds for the construction of a machine for earthquake registration, of which the superintendence is entrusted to the same gentleman.

On Zoology and Animal Physiology I can scarcely venture to offer you a report, beyond a reference to the three papers on Marine Zoology in our last volume,—which I conceive to possess the very highest value. I cannot, however, omit all notice of the last Electro-physiological investigations of Signor Matteucci: investigations which seem to draw more closely the relations of inorganic matter with organic and animated structure than any others with which I am acquainted.

In Vegetable Physiology I must speak in a manner equally undecided. But I need scarcely allude to the interest excited among botanists by the return of Dr. Hooker from his botanical expedition of some years' duration into Upper India and Thibet: an expedition accompanied with great personal danger (for the botanist was for some time detained as captive by one of the native princes), and in which, moreover, the physical geography of a large and hitherto unknown region has been established. In the course of this expedition, a peak 28,000 feet high was partially climbed. In European Botany the inquiries into the reproduction of cryptogamous plants appear to have occupied the most prominent place. I would call your attention to the continuation of the Report on the Growth and Vitality of Seeds, which forms part of our last volume,—and to the Report, which I trust we may soon receive, on the probable effects of the destruction of Tropical forests.

Before quitting the subject of Natural History, I am bound to allude to one subject of great interest to natural philosophers in every branch. It had long been matter of regret to many of the most active members of this Association that the constitution of the immediate ruling body in the British Museum appeared scarcely to offer to them sufficient security for the due support of those natural sciences for which, in a great measure, the Museum was originally founded. So strongly had this been felt, that the Council were prepared to solicit the immediate attention of Government to that point. I am happy now to state that, without the exercise of this interference, the principal ground of alarm has been removed by the appointment of Sir Philip Egerton as one of the Trustees of the British Museum.

I must omit allusion to Geography, Ethnology and Statistics, and proceed to my final subject.

Engineering and Manufacturing Science have always commanded a great

share of the attention of this Association. The former, indeed, when it is made to include experiments on Tides and analogous phænomena, becomes almost one of the cosmical instead of one of the constructive sciences. It would be an endless task for the most accomplished mechanic to attempt to describe to you the inventions which are constantly made in every part of manufacturing science. Confining myself to engineering science, I may state, that in the present partial suspension of railway works, and since the great achievement of the raising of the Britannia Bridge, there appears to be little which has strongly fixed public attention. Considerable importance, however, is attached by engineers to some of the processes lately introduced,—especially that of thrusting down an air-tight tube or elongated diving-bell, supplied with air at the proper pressure, by which men are enabled to perform any kind of work under almost any circumstances, and in which men or materials may be transferred without disturbance of the apparatus, by a contrivance bearing the same relation to air which a common canal-lock does to water. Improvements have also been made in the application of water-pressure to various mechanical purposes. Some years ago, an extensive inquiry into the practical uses and properties of various metals was made by a Committee appointed by the Board of Admiralty. It appeared to the Association a matter of great interest that the Reports of this Committee should be published; and, on their applying to the Admiralty, instructions were immediately given for placing the original Reports in the hands of the Council of the Association. The Council have requested Mr. James Nasmyth to draw up an abstract of the principal contents of these Reports; and this abstract, I hope, will be presented to the present meeting of the Association. Other Reports on important engineering subjects, for which requests were made by the General Committee at the Edinburgh meeting, will, I trust, be communicated to the present meeting. In treating of Practical Mechanics, I may perhaps with propriety allude to the investigations which have lately been made by able engineers regarding the Mechanical Equivalent of Heat. The subject, in this form, is yet new; but I think that the importance of an accurate determination cannot be overrated. This also appears the proper place for alluding to a subject which has attracted the attention of the Association from its very first formation—namely, the simplification of our Patent Laws. The measures of the Government on more than one occasion have shown that they are desirous of removing the impediment which, in this country (strange to say) more than in any other in the world, have been placed in the way of mechanical inventions.

I cannot quit the subject of Manufactures without alluding to a thing which is, so far as I know, perfectly unique in the history of the world,—I

mean the Great Exhibition of the Works of Industry of all Nations. On the present occasion I can do little more than respectfully refer to the interest taken in its establishment by His Royal Highness Prince Albert, without whose zealous support and continued superintendence the undertaking never could have been brought to maturity. I am, however, compelled to cite the labours of His Royal Highness in the cause of the Exhibition, as well as the visit with which in a few hours we hope to be honoured, as a proof how much is common to his desires and to ours. The ultimate effects of an enterprise so vast, so novel, must yet be matter of vague conjecture; but one thing can scarcely be doubted—and in the presence of the many distinguished foreigners near me I see an incontrovertible argument for it,—that the Exhibition will have the effect of uniting more closely than ever the separate nations of the earth by the ties of commerce, of hospitality, and of mutual esteem.

There are two matters, applying generally to the whole of the subjects of which I have spoken, that require notice on the present occasion. The first, which I have very great pleasure in stating, is, that in this year, for the second time, the First Lord of the Treasury has spontaneously placed at the disposal of the Royal Society the sum of 1000*l.*, to be employed at their discretion in assisting private scientific enterprise. The second is, that it is proposed by the Council of the Association so to modify the organization of the Committee of members of Legislature who are also members of the Association as to make it a really efficient body for the purpose of watching the course of legislative measures which may affect the progress of science.

From this very imperfect sketch of the progress of science and of the Association, two things, I think, will be perfectly clear:—first, that there has been no slackness in the progress of science during the last year or the last few years, as compared with that in preceding years; secondly, that in this progress the British Association has taken a most active and efficient part, in all the ways in which it is possible for it to act, by the private labours of its members, by the discussions in its Sections, by the preparation of Reports, by the corporate action of the Association in granting money for purchase of instruments and expense of experiments, by its co-operation with other scientific bodies, and by its immediate influence on the Government. It would not be easy to compare the values of the different results produced in these different ways. Those persons who enter actively into the proceedings of the meetings will set a very high estimate on the personal intercourse and oral discussion of the Sections;—those who purchase its publications are unanimous in regarding its series of Reports as one of the most precious collections of documents ever given to the public; while others

regard as one of its most beneficial effects its influence on the Legislature and on the Executive.

Perhaps this may be a proper opportunity for remarking on the constitution of the Association, and on the mode in which its influence has been acquired and the rules which its structure imposes on its actions. By considering it in relation to other institutions of our country, we shall discover the fitness of its arrangements for the purposes contemplated in its institution; and by studying on the broad scale the history of the past, we shall learn to guide ourselves for the future.

One of the strongly-marked distinctions between Britain and the other states of civilized Europe is this, that we have no Academy of Sciences supported by the State for the express purpose of advancing Science. Even our Universities do not, in their institution, possess this character; they are essentially places of education only,—although, incidentally, they have rendered inestimable service to Science. And this absence of Government-Science harmonizes well with the peculiarities of our social institutions. In Science, as well as in almost everything else, our national genius inclines us to prefer voluntary associations of private persons to organizations of any kind dependent on the State.

It is not to be expected that this condition of things will be perfectly satisfactory to every individual; and, indeed, a wish has sometimes been expressed that an Academy of Sciences were established in Britain. In this wish I, personally, do not join. A great German poet and historian, who was also a profound and practical thinker, has ascribed the boldness and the originality of German literature to the circumstance that it was not encouraged by the most distinguished German princes. He regarded the tendency of such patronage as enfeebling and almost calamitous. I am inclined to apply the same remark, at least to some extent, to Science. I gratefully acknowledge the services which Government has rendered to Science by acceding to the recommendations of this and other bodies who have indisputably established claims to their attention; I think it is honourable and advantageous to every party that the Government should occasionally grant personal rewards for important discoveries; I am of opinion that when any branch of Science has been put in such a form that it admits of continued improvement under a continued administrative routine, that administration should be undertaken by the Government. But I trust that in all cases the initiative of Science will be left to individuals or to independent associations.

In no country, I apprehend, is so much done for Science in private observatories and private laboratories as in this. The future historian of Astronomy will tell of the enormous catalogues of stars observed and the numerous

planets discovered by the telescopes of private observers. The historian of Chemistry will tell that those splendid discoveries which have made a radical change in the science have been made in institutions supported by private subscriptions. The institution of the British Association is an embodiment of the same principle in a different form. To facilitate the intercourse of individuals ardent in the private pursuit of science, it was necessary that its assemblies should be large, and almost unrestricted in admission of members; and this condition necessarily carried with it another, that its meetings should follow at wide intervals. To enable the nation to learn from the provinces and the provinces from the nation, its wandering character is essential.

That in the course of these meetings there has been ample evidence of that stimulation which rarely fails to accompany the assemblage of a great number of persons engaged in singleness of heart on the same general object, can hardly be doubted. In nothing is it more conspicuous than in the production of those elaborate Reports upon which no small portion of our reputation and our utility is founded. It has been remarkable also in the direction of the labours of our members, who have in many instances eagerly taken up the trains of subjects indicated by the Association in its meetings.

But there is another thing into which it is highly important for us to inquire. We communicate with other scientific bodies, British and foreign, and our communications are respected. We offer suggestions to the Government, sometimes implying the outlay of large sums of money,—and our suggestions are never lightly received. How is it that the Association has acquired this external influence?

I answer, that we have bought it. We have bought it by our own personal labours in the same cause for which we solicit the aid of Government. We have bought it by the expenditure of our money in a way which shows that Science alone is our object in soliciting contributions from our members. But, more than all, we have bought it by the care and the caution with which our applications to Government have been made. In no instance, I believe, has a request been urged for the aid of the State in things beyond our power until we had expended our own money on things of the same class within our power. Scarcely can an instance be picked out in which we have not manifested our full acquaintance with every detail of the object to be attained and the ways of attaining it before bringing the matter before the nation for its general assistance. And if I were called on to advise the Association as to the means by which this important external power may be best preserved, I would above all things insist on the most studious caution and the most minute preparation before making application to the Government.

This power of stimulating our own members and this influence on external bodies, as I have stated, are, in my opinion, connected in a great measure with the independent character of our body, as consisting of a mass of independent elements. But with this consideration we must connect another. If we possess the freedom of private persons, we are also under the same restraints as private persons :—and nothing could be more injurious to us than any step which seemed to imply our belief that we, an unauthorized body, could venture to interfere in any matter in which any other company of private persons acting publicly could not interfere. For instance :—I can scarcely imagine a case in which we should be justified in offensively expressing our disapprobation of the course followed by any other person or Society. Again :—The past history of science or invention is matter of innocent interest to us as to others ; but, in my opinion, nothing will justify us in entering on the consideration of claims to priority or superiority in which the reputation or the pecuniary interests of the living are concerned.

And now, Gentlemen, I have only to express my hope that the Meeting at Ipswich may be as fortunate as those which have preceded it. I trust that on the present occasion we may have unusual opportunities of enjoying and profiting by the society of the distinguished foreigners now in England. I trust that the subjects in our Sections may be numerous and interesting, and the discussions on them animated and courteous. I trust that the important Reports which we expect may most fully maintain the character of our annual volume,—and that well-chosen subjects will be proposed for Reports on the experimental investigations of our members for the next year. I trust that your governing body will be bold, yet cautious, in urging on the attention of the Government, or of other bodies, those things which appear necessary for the good of Science. With these wishes, I now commend you to the daily labours of the Meeting.

REPORTS

ON

THE STATE OF SCIENCE.

On Observations of Luminous Meteors; continued from the Report of 1850. By the Rev. BADEN POWELL, *M.A., F.R.S. &c., Savilian Professor of Geometry in the University of Oxford.*

IN presenting a fourth report in continuation of a collection of observations of Luminous Meteors, I have merely to observe that in the present instance, for this first time, the tabular form of arrangement agreed upon by a Committee of the British Association last year, has been adopted by most of the observers: and in connexion with the use of it, I would wish to suggest to those who favour the Association with their contributions, the desirableness of allowing a more distinct space to each individual observation; as it is often necessary to separate them in order to arrange them with others in chronological order.

Besides the assistance of several other friends, I have to acknowledge more especially, as heretofore, the aid of Mr. E. J. Lowe, of Dr. Buist, and the Rev. J. Slatter. Some of the results collected by the British Meteorological Society have also been sent to me; and it is much to be wished that that Society would co-operate with the British Association by regularly furnishing copies of their Meteor Observations for this Report.

As on former occasions many meteors have been communicated to me of a date earlier than the conclusion of the last catalogue: these are here prefixed. It would tend materially to the unity and arrangement of the catalogue if this could be avoided.

Table I.—*Catalogue of Luminous Meteors prior to*

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1848.	h m				
Jan. 2, 3		Extraordinary number of falling stars.			
3	6 0 a.m.	Many falling stars			
12	0 15 a.m.	Igneous globe			
21		Igneous globe			
	6 30 p.m.	Superb bolide			
Mar. 27 & 29.		Many falling stars			
April 27		Many falling stars			
May 2		Large falling stars			
24		Superb bolide			
June 21		Many falling stars			
July 6, 24, 27–31		Many falling stars			
22, 23		Many falling stars			
29	From 10 7 p.m. to 12 7 p.m.	101 in two hours			
Aug. 4	From 9 52 p.m. to 11 58 p.m.	104			
5, 6, 9, 10		Extraordinary number of falling stars.			
9	From 10 21 p.m. to 11 5 p.m.	9			
10	From 2 35 a.m. to 3 8 a.m.	6 large			
28		Many large		Train	
	8 11 p.m.	Superb bolide		Lasted 3 or 4 secs.	
Sept. 4	9 0 p.m.	Vivid ball of fire. Same evening many falling stars.	Brightness = full moon, rather lurid.	When first seen was just bursting in half; scattered sparks in all directions, of various sizes: one mass, nearly $\frac{1}{3}$ of whole, fell rapidly towards S. After falling 25° burst and dissipated.	About 3 mins. gether.
4, 5		Considerable number			
30		Many falling stars			
Oct. 20, 22, 23, 25		Many			
22, 23		Considerable number.			
Nov. 5, 6		Numerous			
12	From 5 47 p.m. to 6 43 p.m.	13			

the Conclusion of the last Catalogue, July 1850.

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
....	Same as observed at Aix-la-Chapelle.	Parma	M. Colla	Bulletin de l'Acad. R. de Bruxelles, 1850, p. 250.
....	....	Aix-la-Chapelle.	M. Ed. Heis......	Ibid. p. 3.
wards N.	Same as observed at Aix-la-Chapelle.	Parma	M. Colla	Ibid. p. 250.
....	Observed at Aix-la-Chapelle.	Ibid...............	Id.	Ibid.
wards S.E.	....	Aix-la-Chapelle.	M. Ed. Heis......	Ibid. p. 3.
....	....	Ibid...............	Id.	Ibid.
....	....	Ibid...............	Id.	Ibid.
....	....	Ibid...............	Id.	Ibid.
m α Herc. to δ Serpentis ...	....	Ibid...............	Id.	Ibid.
....	....	Ibid...............	Id.	Ibid.
....	....	Ibid...............	Id.	Ibid.
....	....	Parma	M. Colla	Ibid. p. 250.
....	....	Aix-la-Chapelle.	M. Ed. Heis......	Ibid. p. 3.
....	....	Ibid...............	Id.	Ibid.
....	....	Parma	M. Colla	Ibid. p. 250.
....	....	Aix-la-Chapelle.	M. Ed. Heis......	Ibid. p. 3.
....	....	Ibid...............	Id.	Ibid.
xting[d]. Æ. 170°, Dec. +63° eared Æ. 280°, Dec. +51°;	....	Ibid...............	Id.	Ibid.
....	....	Ibid...............	Id.	Ibid.
. by S. Alt. about 50° ...	Observer sitting out of doors. Whole view suddenly illuminated.	Ventnor, Isle of Wight. Seen also in Hampshire at 40 miles W. and in Sussex, 40 miles E.	Mrs. Dixon	MS. com. to Prof. Powell. Appendix, No. 1.
....	....	Parma	M. Colla	Bulletin de l'Acad. R. de Bruxelles, 1850, p. 250.
....	....	Aix-la-Chapelle.	M. Ed. Heis......	Ibid. p. 3.
....	....	Ibid...............	Id.	Ibid.
....	Observed at Aix-la-Chapelle.	Parma	M. Colla	Ibid. p. 250.
....	....	Aix-la-Chapelle.	M. Ed. Heis......	Ibid. p. 3.

Date.	Hour.	Appearance or Magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1848. Nov. 15	h m From 7 8 p.m. to 8 58 p.m.	22 .... Bolide = ♀ (full moon).	....	....	....
Dec. 11	From 5 38 p.m. to 6 50 p.m.	10. Many large, and with trains.	....	....	....
14, 15	....	Many .... [stars.	....	....	....
1849. Jan. 18	....	Numerous shooting	....	....	....
April 30	8 0 p.m.	A luminous elongated body.	Brightness = that of a star of 1st mag.; white; no twinkling.	Train	Slow; visible ne[ar] 30 secs.
Aug. 8	....	106	....	....	....
9	9 0 p.m.	Globe meteor	Bluish, brighter than ♀.	Vanished, leaving a train which lasted 6 or 8 mins.	
	9 5 p.m.	Two superb meteors..	= ♀	No explosion	....
	From 9 30 p.m. to 10 30 p.m.	42, some singly; 20 at once.	....	Some with trains lasting from 2 to 4 secs.	....
	From 9 40 p.m. to 10 p.m.	9 shooting stars	....	....	....
	From 10 0 p.m. to 11 p.m.	9 shooting stars	....	....	....
9 & 10	....	Mean no. per hour 28	....	....	....
10	From 9 0 p.m. to 2 0 a.m.	254 shooting stars ...	22 of 1st mag.	88 with trains........	....
	From 9 14 p.m. to 10 50 p.m.	22 falling stars, some = 1st mag.	....	....	....
	From 9 24 p.m. to 1 35 a.m.	13........	....	....	....
	From 9 45 p.m. to 10 p.m.	6 shooting stars	....	....	....
	From 10 0 p.m. to 11 p.m.	23 shooting stars........	....	....	....
	From 11 0 p.m. to 11 45 p.m.	9 shooting stars	....	....	....
	From 11 43 p.m. to 11 8 a.m.	5	....	....	....

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
ppeared Æ. 102°, Dec. 32°; extingd. Æ. 108°, Dec. 26°.	....	Aix-la-Chapelle.	M. Ed. Heis......	Bulletin de l'Acad. R. de Bruxelles, 1850, p. 3.
....	....	Ibid..............	Id.	Ibid.
....	....	Parma	M. Colla	Ibid. p. 250.
....	....	Ibid..............	Id.	Ibid.
st seen not much above horizon in N.W.; descended to horizon at inclination 45°.	....	Liège	M. De Koninck..	Ibid. p. 177.
....	....	Berne	Correspondent...	Ibid. p. 367.
om Pegasus towards Aquarius.	Seen also at Neustadt, by M. Mayer.	Parma	M. Colla	Ibid. p. 364.
....	....	Neustadt, near Vienna.	M. Mayer.........	Ibid.
om zenith towards N.W. ...	....	Ibid..............	Id.	Ibid.
....	....	Ghent	M. Duprez	Ibid. p. 320.
....	....	Ibid..............	Id.	Ibid.
....	....	Bruxelles.........	M. Quetelet......	Ibid.
3° from a point in Perseus; Æ. 50°, Dec. 51°. 44° from Draco; Æ. 302°, Dec. 65°. 19° from near Pole; Æ. 337°, Dec. 86°.	....	Aix-la-Chapelle.	M. Heis	Ibid. p. 367.
peared in various constellations.	....	Parma	M. Colla	Ibid. p. 363.
....	....	Bonn	M. Schmidt......	Ibid. p. 367.
....	....	Ghent	M. Duprez	Ibid. p. 320.
....	....	Ibid..............	Id.	Ibid.
....	....	Ibid..............	Id.	Ibid.
apparent divergence from one centre; mostly from N. to S.	....	Parma	M. Colla	Ibid. p. 363.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1849.	h m				
Aug. 10	From 0 8 a.m. to 2 a.m.	None	....	....	....
	0 44 a.m.	1, extraordinarily [bright.	Red	....	....
	....	370	....	....	....
10, 11	....	Many	....	....	....
11	From 9 0 p.m. to 12 p.m.	114	....	....	....
	From 9 24 p.m. to 1 35 a.m.	65........	....	....	....
		133	....	....	....
		20........	....	....	....
		35........	....	....	....
		29........	....	....	....
		71........	....	....	....
		52........	....	....	....
		79........	....	....	....
		36........	....	....	....
13	....	22........	....	....	....
14	....	27........	....	....	....
15	....	36........	....	....	....
Sept. 3	....	= 1st mag.	Very brilliant bright red. When the flames appeared it was almost as bright as lightning.	Train of sparks	Rapid. The flan lasted from 5 7 secs.
Dec. 21	5 0 & few minutes.	....	Far exceeded Venus.	....	....
30	5 45 p.m.	= $\frac{1}{8}$ ☾'s diameter ...	Like a globe of bright light. For a moment a perfect sphere.	It then burst near its N. point, and emitted upwards a knotted stream of red light in a direction N. by E. and at an angle of about 18° from a vertical line. The length of this projected stream of light was 10 diameters of the ☾.	....
1850.					
Feb. 3	11 0 p.m.	A meteor	....	....	....
5	6 50 p.m.	Dull disk, increased till = $\frac{1}{3}$ more.	Reddish	Burst, discharging red fragments and bright train perpendicularly down.	Stationary at : for 1 min. 45 s till explosion ter which body slowly ved horizon for 45 secs.

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
....	....	Parma	M. Colla	Bulletin de l'Acad. R. de Bruxelles, 1850, p. 363.
om γ Cygni to α Androm. ...	....	Aix-la-Chapelle.	M. Ed. Heis......	Ibid. p. 367.
....	....	Berne	Correspondent...	Ibid.
ı all points of horizon.........	....	Chanberry	Id.	Ibid. p. 364.
° from Perseus (as above); 28° from Draco (as above); 18° from inner Pole (as above).	....	Aix-la-Chapelle.	M. Heis	Ibid. p. 367.
....	....	Bonn	M. Schmidt......	Ibid.
....	....	Berne	Correspondents..	Ibid.
....	....	Frankfort......		
....	....	Neurkircken..		
....	....	Hamburgh ...		
....	....	Bremen		
....	....	Dilke		
....	....	Breslau		
....	....	Timmel		
....	....	Ibid............		
....	....	Ibid............		
....	....	Ibid............		
t. 40° in N.E., and moved horizontally to N.W., where, instead of giving out a mere brilliancy of sparks, it burst into a full blaze (like a wisp of straw). The blaze had the appearance of being about 1 foot in length (doubtless it was many yards) [?]. It rose directly upwards like any other flame, and had a large, wavy, upright motion. No stars were visible, as the twilight was so strong.	....	Between Belton and Castle Donington.	Rev. J. Dalby ...	Mr. Lowe's MS.
oved downwards through a short arc, exploded into numerous fragments at an alt. of 20° to 30°.	....	New Haven, U.S.	....	New Haven Palladium.
....	Also seen at Aylesbury, Weeden and Dunton, exhibiting the same phænomena.	Between Hartwell and Stone Observatory.	Rev. C. Lowndes	Mr. Lowe's MS.
....	....	Hartwell Rectory near Aylesbury	Rev. C. Lowndes	Ibid.
t 28° 30′ at first appearance..	General appearance remarkable.	Sandwich, Kent..	W. H. Weekes, Esq.	Communicated by Mr. Lowe. See Appendix, No. 2.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850.	h m				
Feb. 9	11 15 p.m.	....	....	....	....
11	10 37 p.m.	A large meteor	Light only seen	....	....
	10 35 p.m.	"An immense light shone in at the window of a spare room in which I happened to be, so bright as to cast even a shadow of the irregularities of the glass, but it had ceased before I could reach the window, the access to which was blocked with furniture."	....	The explosion in about 1 minute.	....
April 1	....	Very brilliant	....	....	....
10	10 0 p.m.	....	....	....	....
May 2	....	Increased as it descended till nearly = ♃.	Pure white ...	Vanished, no explosion, no train.	....
4	10 0 p.m.	....	....	....	....
29	10 5 p.m.	....	....	....	....
June 4	11 28 p.m.	....	....	....	....
10	10 12 p.m.	Very brilliant	Increased in size.	Burst into luminous fragments.	Shot rapidly acr
16	12 25 p.m.	....	....	....	....
	12 40 p.m.	Larger than 1st mag. *	Blue............	Train left 20° in length ...	....
	12 40 & few secs.	Small	....	....	....
	12 45 p.m.	....	....	....	....
	1 3 a.m.	....	....	....	....
	1 20 a.m.	= 1st mag.	Beautiful red..	....	....
20	11 42 p.m.	....	....	....	....
24	11 30 p.m.	= 1st mag.	Blue............	Train left........................	....
		....	....	....	....
30	11 0 p.m.	= 1st mag.	White	No tail..........................	....
		Table II.—*Catalogue of Luminous Meteors, continued*			
July 1	7 30 p.m.	....	Bright	Exploded with a bright flash and burst into sparks	....
4	9 25 p.m.	Increased in size; became very large.	Became very bright. Silvery blue.	At last a few sparks	Duration 2 secs.
	9 26 p.m.	From a mere point increased to 3 times diameter of ♃.	6 times brighter than ♃. Pale blue.	At first no sparks	Duration 2 secs.

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
ies to Orion......................	....	[near Aylesbury. HartwellRectory,	Rev. C. Lowndes	Mr. Lowe's MS.
oise heard, resembled the falling of a distant avalanche.	....	Ibid..................	Id.	Ibid.
....	....	Rose Hill, near Oxford, lat. 51°43′ 50″N. long.1°14′08″W.	Rev. J. Slatter...	Communication to Prof. Powell.
....	....	Aden	Correspondent to Dr. Buist.	See Appendix, No. 11.
piter to γ Leonis...............	....	Stone Observatory.	Rev. J. B. Reade.	British Meteorological Soc. Report.
E. Alt. 45°; fell nearly 20°	....	Byculłah, Bombay.	Correspondent to Dr. Buist.	See Appendix, No. 11.
Virgo, 4° from Jupiter to Jupiter.	....	Stone Observatory.	Rev. J. B. Reade	British Meteorological Soc. Report.
om α Cygni southwards	....	Ibid..................	Id.	Ibid.
laris to δ Ursæ Majoris	....	Ib.; also at Hartwell Rectory.	Id., and Rev. C. Lowndes.	Ibid.
om near Scorpio S.W. to N.E.	$\frac{1}{4}$ min. after, report lasting $\frac{1}{2}$ min.	....	Mr. Brown, correspondent to Dr. Buist.	See Appendix, No. 13.
est of β Cassiopeiæ; went 4°N.	....	StoneObservat^y.	Rev. J. B. Reade	B. M. S. Report.
om W. of Capella 10° E. of due N. and 15 above horizon, and went in W. direction near 31 Lyncis.	....	Ibid..................	Id.	Ibid.
ove Polaris to Cassiopeia ...	....	Ibid..................	Id.	Ibid.
erpentis; went 5° S.	....	Ibid..................	Id.	Ibid.
ootis to Arcturus	....	Ibid..................	Id.	Ibid.
om ϵ passing by α Urs. Maj..	....	Ibid..................	Id.	Ibid.
yræ to α Cygni	....	Ibid..................	Id.	Ibid.
cturus went 20° magnetic W.	....	Ibid..................	Id.	Ibid.
cturus to within 10° of horizon	....	Ibid..................	Id.	Ibid.
om α Coronæ Borealis to ϵ Serpentis.	....	Castle Donington, near Derby	Rev. S. K. Swann	Mr. Lowe's MS.

from the Conclusion of the last Catalogue, July 1850.

om S.E. to N.W. for about 20°; exploded at alt. 70° ...	....	Bombay	Correspondent to Dr. Buist.	See Appendix, No. 14.
arer χ than ϑ Antinoi, and rather above the level of those stars, to α Capricorni.	The same as one observed at Beeston, but apparently seen more southerly than at Beeston.	Highfield House.	A. S. H. Lowe, Esq.	Mr. Lowe's MS.
sed $\frac{1}{2}$ between λ and θ Antinoi to 2° E. and same level s α Capricorni.	On bursting disappeared suddenly.	Stonyhurst Observatory.	Rev. A. Weld ...	B. M. S. Report.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850.	h m				
July 9	10 0 p.m.	Twice the size of ♃ ...	Colour of ♃ ...	....	....
		Twice the apparent size of ♃.	Same colour as ♃.	....	....
12, 16, 30.	....	Meteors very numerous.	....	....	....
13	11 20 p.m.	....	....	....	....
14	8 54 $2^s \cdot 42$ Grantham M.T. (Nearly daylight, no stars to be seen.)	Large	=to Venus as a morning *. White (⊙ on the point of vision).	On bursting left a train of light 1° in length, at an altitude of 25°.	Time 2 secs. N report heard, a though listene for.
	8 54 p.m.	Large	....	Slight smoke	....
16	9 30 p.m.	Several luminous balls.	....	With streams of light......	Slow............
23	....	Very fine night; no meteors; the 24th was cloudy.	....	....	....
25	9 57 20^s	From 4th to 5th mag.	....	....	Duration 1 sec. .
	9 57 25^s	From 4th to 5th mag.	....	....	Duration 1 sec. .
	11 05 p.m. G.M.T.	4th mag.	Small	....	2 or 3 secs. ......
	0 16 a.m. G.M.T.	3rd mag.	Bright	....	Momentary ......
29	9 57 p.m.	....	....	....	....
31	10 21 p.m.	=3rd mag.	....	....	Immediate ......
	10 22 p.m.	=2nd mag.	....	....	Visible ½ sec. ...
	10 25 p.m.	=3rd mag.	....	....	Duration 2 secs.
August 1	10 0 p.m.	Small	....	Train of light	....
		Small	....	Train of light	....
3	9 50 p.m.	=4th mag.	....	....	Time 1 sec. ......
	10 55 p.m.	=5th mag.	....	....	Duration $0^s \cdot 5$ ..
		=5th mag.	Red	....	Duration ½ sec.; 1 tion tolerably ra
		=4th mag.	Red	....	Duration ½ sec.; 1 tion tolerably ra
6	9 45 p.m.	1 mag., bright as Arcturus.	....	*Coarse* sparks	2 or 3 secs. ......
	9 50 p.m.	2nd mag.	....	*Fine* sparks	2 or 3 secs. ....
	9 53 p.m.	3rd mag.	....	None	2 or 3 secs. ....
*	9 55 p.m.	3rd mag.	....	None	2 or 3 secs. ....
	9 57 p.m.	4th mag.	....	None	2 or 3 secs. ....
	9 58 p.m.	1st mag.	....	None	Momentary ....
	10 03 p.m.	1st mag.	....	Sparks	2 or 3 secs. ....
	10 05 p.m.	2nd mag.	....	None	2 or 3 secs. ....

* The courses of all the meteors of Aug. 6, produced backwards, meet in $IV^h\ 00^m$ Æ 45° N.P.D. gravity: such was that of July 25th. The following days spent in Monmouthshire the weather

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
ll down from Coma Berenices	....	Stonyhurst Obs^y.	Rev. A. Weld ...	B. M. S. Report.
t. 50°; fell perpendic. down for 7° in due west.	....	Highfield House.	A. S. H. Lowe, Esq.	Mr. Lowe's MS.
....	....	Uckfield, Sussex.	C. L. Prince, Esq.	B. M. S. Report.
om Arcturus to Peterson's comet.	....	Stone Observatory.	Rev. J. B. Reade	Ibid.
t. 50° to 55°; fell perpendicular down for 25°; direction 8° or 10° N. of E.	....	1½ mile from Grantham.	J. W. Jeans, Esq.	Mr. Lowe's MS.
....	Crackling noise heard.	Boston	....	Boston Papers.
om S.W. to S., through 10° or 12°.	Amid electric coruscations; the balls moved along the streams.	Manchester	P. Clare, Esq.	Brit. Assoc. Report, 1850, Trans. Sect. p. 31.
....	....	Tenby, N. lat. 51° 40′ 55″ W. long. 4° 38′	Rev. J. Slatter...	Com. to Prof. Powell.
ar α Geminorum towards Arcturus.	....	Castle Donington	W. H. Leeson, Esq.	Mr. Lowe's MS.
Draconis to 2° below δ Urs. Maj.	....	Ibid..............	Id.	Ibid.
ove α and below β & γ Androm.	....	Tenby	Rev. J. Slatter...	Com. to Prof. Powell.
down for β Andromedæ......	....	Ibid..............	Id.	Ibid.
ossed Corona Borealis from N. to S.	....	Stone Observatory.	Rev. J. B. Reade	B. M. S. Report.
N. of γ Herculis; disappeared without any visible motion.	....	Darlington, near Durham.	J. Graham, Esq.	Ibid.
ar α Coronæ Borealis; moved 2° perpendic. down.	....	Ibid..............	Id.	Ibid.
Coronæ Borealis passed a little W. of β Serpentarii.	....	Ibid..............	Id.	Ibid.
o zenith in S.S.E. perpendic. down.	....	Highfield House.	A. S. H. Lowe, Esq.	Mr. Lowe's MS.
om α Aquilæ downwards......	....	Stonyhurst Obs^y.	Rev. A. Weld ...	B. M. S. Report.
st under α Draconis to midway between γ and β Urs. Maj.	....	Castle Donington	W. H. Leeson, Esq.	Mr. Lowe's MS.
om α Cor. Borealis to ζ Bootis	....	Stonyhurst Obs^y.	Rev. A. Weld ...	B. M. S. Report.
om α Coronæ Borealis to ζ Bootis.	Instantaneous extinction.	Nottingham......	E. J. Lowe	Mr. Lowe's MS.
om ε to η Bootis	Instantaneous extinction.	Highfield House.	A.S.H.Lowe, Esq	Ibid.
' below Arcturus..............	....	Rose Hill, Oxford.	Rev. J. Slatter...	Communicated to Prof. Powell.
tween ζ and η Urs. Maj......	....	Ibid..............	Id.	Ibid.
tween 10 and 11 Camelop....	....	Ibid..............	Id.	Ibid.
& δ U. Maj. between γ & β.	....	Ibid..............	Id.	Ibid.
ne last as much right of β....	....	Ibid..............	Id.	Ibid.
Perseus	....	Ibid..............	Id.	Ibid.
rough χ Persei	....	Ibid..............	Id.	Ibid.
low ε and β Persei	....	Ibid..............	Id.	Ibid.

...ting those at $9^h\ 55^m$, 57^m, 58^m, and $2^h\ 15^m$, which seemed to have no projectile force to fall from ...ldy. Sea extremely phosphorescent on Aug. 6.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850.	h m				
August 6	2 10 a.m.	2nd mag.		None	2 or 3 secs.
	2 11 a.m.	2nd mag.		Train	2 or 3 secs.
	2 15 a.m.	2nd mag.		None	2 or 3 secs.
	10 0 p.m.				
	10 22 p.m.	= to Sirius		Train of light which lingered for 20 secs. in the sky.	
	10 36 p.m.	= to Arcturus	= to Arcturus.	Brilliant train of 15° in length.	Duration 4 secs.
	10 38 p.m.	= 3rd mag.		Train	Duration $1^s{\cdot}5$
	10 41 30^s	= 3rd mag.		Train	1 sec. over 15° space.
	10 52 30^s	= 4th mag.			Quick
	10 56 30^s	= 4th mag.			Quick
8	10 20 p.m.				
	11 15 p.m.				
9		Cloudy; no meteors seen.			
	From 9 30 p.m. to 11 p.m.	40 shooting stars			
	9 45 p.m.	= 3rd mag.			Less than 1 sec.
	9 48 30^s	= 4th mag.			Time 1 sec.
	9 49 p.m.	Much larger than Vega.	Very brilliant.	Left a visible train	Motion at first sl and waved; du tion 2 secs.
	9 50 p.m.				
		Small			Time ½ sec.
	9 57 p.m.	= 1st mag.		Train	Time 1 sec.
	10 0 p.m.	Small			Time ½ sec.
		Small			Time ½ sec.
	10 1 p.m.			Train of light visible for some seconds.	
	10 1 2^s	Small			Instantaneous
	10 1 3^s	= 2nd mag.		Train	Time 2 secs.
	10 3 p.m.	= 1st mag.	Red		
	10 5 p.m.	= 3rd mag.	White		
	10 6 p.m.				
	10 8 p.m.	Small			
	10 10 p.m.	= 3rd mag.	White		
	10 15 p.m.	= 4th mag.			

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
ırough Pleiades	....	Rose Hill, Oxford.	Rev. J. Slatter...	Communicated to Prof. Powell.
ıme course as last	....	Ibid...............	Id.	Ibid.
E. of β Tauri	....	Ibid...............	Id.	Ibid.
....	3 meteors in S.E....	Highfield House.	A.S.H.Lowe, Esq	Mr. Lowe's MS.
om ϵ Pegasi to β Aquarii ...	....	Ibid...............	Id.	Ibid.
below α Coronæ Borealis and 3° below δ Serpentarii; its path convex to those stars, moved over 30° of space.	....	Darlington	J. Graham, Esq.	Ibid.
below α Coronæ Borealis and ½ betwixt δ Serpentarii and ζ Bootis; moved through 20° of space.	....	Ibid...............	Id.	Ibid.
ɪar γ Herculis passed ½ between α and δ Serpentarii.	....	Ibid...............	Id.	Ibid.
Ophiuchi passed between γ Serpentarii and 35 Ophiuchi..	....	Ibid...............	Id.	Ibid.
ɔove O Ophiuchi and through γ Serpentarii; its path parallel to the last.	....	Ibid...............	Id.	Ibid.
N.W. from ϵ Ursæ Majoris...	....	Highfield House.	A.S.H. Lowe, Esq	Ibid.
S.W. from α Ophiuchi	....	Ibid...............	Id.	Ibid.
....	Limited view of sky from buildings, looking towards S.	New Coll. Lane, Oxford.	Prof. Powell.	
....	....	Haverhill.........	Mrs. W. W. Boreham.	MS. communication to Prof. Powell. See Append. No. 5.
Ursæ Minoris to near ϵ Ursæ Majoris.	....	Castle Donington, near Derby	W. H. Leeson, Esq.	E. J. Lowe.
laris to midway between α and κ Draconis.	....	Ibid...............	Id.	Ibid.
ɔm α Lyræ in the direction of Arcturus.	....	Ibid...............	Id.	Ibid.
ɪar ζ Cygni to near α Aquilæ.	....	Ibid...............	Rev. S. K. Swann Rev. J. Sowter...	Ibid.
Delphini to ϑ Aquilæ	....	Ibid...............	W.H.Leeson, Esq	Ibid.
Vulpeculæ to η Serpentis	....	Ibid...............	Id.	Ibid.
Lyræ towards Arcturus	....	Ibid...............	Id.	Ibid.
rough Vulpecula..............	....	Ibid...............	Id.	Ibid.
ar zenith....................	....	Highfield House.	A.S.H.Lowe, Esq	Ibid.
ssed through the zenith......	....	Ibid...............	Id.	Ibid.
ssed just above Polaris	....	Castle Donington	W.H.Leeson, Esq	Ibid.
ɪair perpendic. to horizon ...	....	Ibid...............	Id.	Ibid.
ar ψ Sagittarii.................	....	Ibid...............	Rev. S. K. Swann	Ibid.
ar ϵ Sagittarii	....	Ibid...............	Id.	Ibid.
ven meteors were seen within 1 minute in Great Bear, Lyra and Camelopardalus, but in too rapid succession to note them with precision.	....	Ibid...............	W.H.Leeson, Esq	Ibid.
neb. towards horizon.........	....	Ibid...............	Id.	Ibid.
lebaran towards Polaris......	....	Ibid...............	Id.	Ibid.
ɔm γ Pegasi	....	Ibid...............	Rev. J. Sowter...	Ibid.
Aquarius.....................	....	Ibid...............	Id. .... Rev. S. K. Swann	Ibid.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850. August 9	h m 10 20 p.m.	=2nd mag.	Red	...	...
		In $1\frac{1}{2}$ hour 75 meteors. All except 4 or 5 emanated from a point near β Camelopardali.	...	...	...
		Meteors very numerous.	...	...	...
10	Cloudy. Some clear intervals.	No meteors seen.			
	10 0 p.m. (about).	Nearly = to full ☾ ...	At first reddish, afterwards brilliant blue. The light cast strong shadows of objects.	Its train consisted of three long tails which remained waving backwards and forwards for 30 secs. after the meteor had disappeared.	...
	10 0 p.m.	=1st mag.	Bright	Bright train	Time $1\frac{1}{2}$ sec.
	10 1 p.m.	Large	Bright	Left a train	Visible 2 secs.
	10 5 p.m.	=3rd mag.	...	...	Time 1 sec.
	10 6 30^s	Small	...	...	Very rapid
		Very small	...	...	Very rapid
	10 10 p.m.	=3rd mag.	...	...	...
11	From 9 15 p.m. to 11 p.m.	55 shooting stars ...	...	...	...
	9 30 p.m.	=2nd mag.	Brilliant	Train; no explosion	Instantaneous
	9 35 p.m. (partly clouded)	=1st mag.	...	Brilliant train	Instantaneous
	9 50 p.m. (clouded over)	=1st mag.	...	Brilliant train	Instantaneous
	10 10 p.m.	Large	...	...	...
	=10 12 14^s (G.M.T.)	...	Light, gave a distinct shadow.		
	10 14 p.m.	...	One (marked 1^m) of extraordinary brilliancy.	Luminous track, lasted 30 secs.	...
	10 15 p.m.	Bright flash in W.; from centre a luminous line running E. and W., first red, then paler light, darting backwards and forwards along the line, became indistinct and faded away. Shooting stars numerous.	...	...	Visible about secs.
	10 23 p.m. (partly clear)	=1st mag.	...	Brilliant train	Instantaneous
	10 30 p.m. (entirely clouded)	...	...	...	...

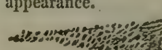
Direction or altitude.	General remarks.	Place.	Observer.	Reference.
...th short and inclined 20° to horizon, passed between α and β Sagittarii.	....	Castle Donington	Rev. J. Sowter...	Mr. Lowe's MS.
....	....	Collingwood, Hawkhurst, Kent.	....	Letter to Prof. Powell. See Appendix, No. 3.
....	....	Uckfield	C. L. Prince, Esq.	B. M. S. Report.
...bout 50° above N.E. horizon, passing through the Galaxy and proceeding some distance further in a S.W. course.	....	Tipperary.........	Correspondent...	Illustrated London News.
...rsæ Majoris towards Arcturus	....	Castle Donington	W.H.Leeson, Esq	Mr. Lowe's MS.
...idway between ε Ursæ Majoris and Cor. Caroli towards Arcturus; it exploded like a rocket.	....	Ibid...............	Id.	Ibid.
...ssiopeia towards α Lyræ......	....	Ibid...............	Id.	Ibid.
...ear α Ursæ Majoris	....	Ibid...............	Id.	Ibid.
...ear α Ursæ Majoris	....	Ibid...............	Id.	Ibid.
...om zenith passed just below α Lyræ; lost in a cloud.	....	Ibid...............	Id.	Ibid.
....	....	Haverhill.........	Mrs. W. Boreham.	See Appendix, No. 5.
... of meridian, inclining to S.S.W. from Cygnus towards Ophiuchus.	Disappeared behind buildings.	New Coll. Lane, Oxford.	Prof. Powell.	
...rough Hercules perpendicular to horizon.	Ditto.	Ibid...............	Id.	
...om near α Aquilæ to Sagittarius; course inclined 45° to meridian.	Ditto.	Ibid...............	Id.	
....	....	Hartwell Rectory	Rev. C. Lowndes	B. M. S. Report.
....	....	....	....	Ibid.
....	....	South Claydon, Bucks.	Rev. J. J. Irwin..	Times, Aug. 15; and subsequent letter to Prof. Powell. See Appendix, No. 4.
...om α Lyræ towards Ophiuchus.	Disappeared behind buildings.	New Coll. Lane, Oxford.	Prof. Powell.	
... of meridian; slightly inclined.	Ditto	Ibid...............	Id.	

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850.	h m				
Aug. 12	8 0 p.m. (soon after)	½ size of full ☾	Equal to the rising ☾.	....	Duration 15 secs
	10 22 p.m. (G.M.T.)	3rd mag.	....	....	1 sec. ....
	† 10 22 15ˢ	4th mag.	....	....	Momentary ......
	‡ 10 23 p.m.	3rd mag.	....	....	Momentary ......
	10 31 p.m.	Like a spark	Yellow	Slight streak	Lasted ⅓ sec.; ve rapid.
	10 32 p.m.	At first =5th mag.; at last =3rd mag.	Blue; it increased in brilliancy.	....	¼ of a second ...
	10 32 15ˢ	=5th mag.	Blue............	Divided streak	¼ sec. ....
	10 33 p.m.	=3rd mag.	Blue............	Streak	½ sec. ....
	11 9 p.m.	12′ in diam. and globular.	Yellow	Train of light	Slow..............
	....	Shooting stars numerous.	....	....	....
	11 40 p.m.	A shower of meteors, too many to count, all having the same origin and direction, only a few degrees above horizon and descending to it about S.E. by S.	....	....	....
13	10 7 p.m.	Very small	....	Splendid train...............	Over 5° in 1 sec.
	10 55 p.m.	=3rd mag.	....	....	Over 10° in 1 se
	10 57 p.m.	=3rd mag.	....	....	Over 12° in 1 se
	11 15 p.m.	Bright meteor.........	....	Leaving a long bright streak.	....
14	8 45 p.m.	4 or 5 times larger than ♃.	Pale straw ...	No tail........................	Duration 2 secs
	9 48 p.m.	Small, =4th mag. ...	Yellow..........	No tail........................	Duration 1 sec.
	9 49 p.m.	=3rd mag..............	Blue............	....	....
	10 0 p.m.	....	....	....	....
	10 0 p.m.	=3rd mag.	White	....	....
	10 9 p.m.	=to α Aquilæ	Colour of α Aquilæ.	....	....
	10 24 p.m.	=1st mag.	....	Splendid train, 15° long...	Over 20° in 4 s

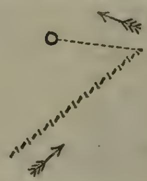
† From a point about XIXʰ 00 Æ 100° N.I

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
oving towards the S.W.	....	Penzance, Cornwall.	R. Edmonds, jun., Esq.	Mr. Lowe's MS.
tween α and β Capricorn. ...	....	Rose Hill, Oxford	Rev. J. Slatter...	Com. to Prof. Powell
low feet of Capricorn.........	....	Ibid................	Id.	Ibid.
low Scorpio......................	....	Ibid................	Id.	Ibid.
om τ Cassiopeiæ to below Polaris.	Had the appearance of a spark very near us.	Highfield House	E. J. Lowe, Esq.	Mr. Lowe's MS.
rizontally from H. 24 Camelopardi towards λ Draconis.	....	Ibid................	Id.	Ibid.
ved perpendicularly up for 1° from τ Cassiopeiæ.	....	Ibid................	Id.	Ibid.
om C. II. 157 Lyncis, towards ρ Ursæ Majoris.	....	Ibid................	Id.	Ibid.
om β, γ & λ Pegasi perpendic. lown to within 20° of horizon, when it went behind a cloud.	In 1 to 2 secs. after a flash resembling lightning, and as vivid, and immediately a second from the same cloud.	Highfield House.	E. J. Lowe, Esq.	B. M. S. Report.
....	....	Ibid................	Id.	Ibid.
....	....	South Claydon, Bucks.	Rev. J. J. Irwin..	Times, Aug. 15; and subsequent letter to Prof. Powell. See Appendix, No. 4.
above γ Persei; its path early parallel to horizon, out dipped a little.	....	Darlington	J. Graham, Esq.	Mr. Lowe's MS.
above β Herculis, and parallel with it and 19 Herculis.	....	Ibid................	Id.	Ibid.
Equulei to near 64 Capricorni	....	Ibid................	Id.	Ibid.
m below β Aquilæ to just bove Fomalhaut, moving early horizontally from E. owards S.	....	Port Madoc, Caernarvonsh.	Mrs. Smyth......	Letter to Prof. Powell. See Appendix, No. 3.
m between λ Bootis and Ursæ Majoris perpendicuarly down, inclining slightly orth; passed near Cor. Caoli and about 3° to 4° N. of he large group in Corona Beenices.	Circular, well-defined disc.	Beeston Railway Station, 1¼ mile S. of Highfield House.	R. Enfield, Esq.	Mr. Lowe's MS.
m H. 24 Camelopardi to Ursæ Majoris.	....	Highfield House.	E. J. Lowe, Esq.	Ibid.
pendicularly down from Cassiopeiæ.	....	Ibid................	Id.	Ibid.
....	A meteor...........	Ibid................	A.S.H. Lowe, Esq	Ibid.
ygni to ½ γ Pegasi	....	Castle Donington	Rev. J. Sowter...	Ibid.
r α Aquilæ	....	Ibid................	Id.	Ibid.
out 30° N. of α Herculis and 15° S. of β Ophiuchi.	....	Darlington	J. Graham, Esq.	Ibid.

eemed at right angles with others with no projectile force.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850. Aug. 14	h m 10 28 p.m.	=2nd mag.		Bright train, 12° long	Over 15° in 2 se
	10 35 p.m.	4th mag.			1 sec.
15	9 35 p.m.	Small			
		Large	Much brighter than 1st mag.	Visible train left	Time $2\frac{1}{2}$ secs.
					
18	2 00† a.m.	2nd mag.			2 secs.
	9 30 p.m.	=3rd mag.			Over 10° in 1 se
20	7 50? twilight.	1st mag.			1 sec.
22	10 0 p.m.				
	10 24 p.m.	=to Arcturus	Yellow		Duration 1 sec.
	14 25 p.m.	Twice the size of ♃	Yellow	Slight train	
29	9 55 p.m.	=3rd mag.		Train	Over 20° in 2 s
	9 59 35ˢ	=3rd mag.	Duration $\frac{1}{2}$ sec. Blue.		Duration $\frac{1}{2}$ sec.
	10 1 p.m.	=2nd mag.	Red	Left a red train of sparks	Rapid
	10 2 p.m.	=2nd mag.		Magnificent train, fully 25° long.	Over 45° in 8 s
	10 3 p.m.	At first = 5th mag. star, at last 3 times size of Saturn.	Orange-scarlet	Fragments This diagram will show the appearance. 	Slow, duratio secs.
	10 4 p.m.	=2nd mag.		Train of at least 30° in length.	Over 40° in 6
	10 15 p.m.	=3rd mag.			Rapid
	10 20 p.m.	=1st mag.			

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
ırough β Lyræ and 1° E. of β Cygni.	....	Darlington	J. Graham, Esq.	MS. of E. J. Lowe.
ɔove α Pers. Gave same centre as in Aug. 6	....	Rose Hill, Oxford.	Rev. J. Slatter...	Communicated to Prof. Powell.
om ν to θ Ursæ Majoris	....	Castle Donington	Rev. J. Dalby ...	Mr. Lowe's MS.
om a point nearly 10° left of α Lyræ in a vertical direction towards horizon; exploded like a rocket; at starting it appeared rather small, gradually increased, then decreased; for an instant disappeared, then increased, and decreased again. (See fig.)	....	Near Union House, Shardlow (near Castle Donington).	W. H. Leeson, Esq.	Ibid.
ırough Cetus above β from head of Cetus	....	Rose Hill, Oxford.	Rev. J. Slatter...	Communicated to Prof. Powell.
om 15 Persei, and moved nearly parallel with γ and α Persei, being nearly perpendic. with horizon.	....	Darlington	J. Graham, Esq.	Mr. Lowe's MS.
down from Urs. Maj.	....	Rose Hill, Oxford.	Rev. J. Slatter...	Communicated to Prof. Powell.
ɔm zenith towards E., passing S. of α Cassiopeiæ.	....	Highfield House.	A. S. H. Lowe, Esq.	Mr. Lowe's MS.
arly perpendic. down, inclining to N. from 5° below γ Bootis.	....	Ibid................	E. J. Lowe	Ibid.
ɔm α to χ Ursæ Majoris......	Rather rapid	Nottingham......	G. Allcock, Esq.	Ibid.
rough π Andromedæ and about 1° N. of ζ Andromedæ.	....	Darlington	J. Graham, Esq.	Ibid.
ɔm μ Bootis to Arcturus......	Rapid	Highfield House.	E. J. Lowe, Esq.	Ibid.
ɔm γ Trianguli to Saturn (*i. e.* near ε Piscium).	....	Ibid................	Id.	Ibid.
rough 11 Muscæ Borealis, slightly above α Arietis and 1° below γ Pegasi; as it moved along, an increase in its apparent alt. was evident.	....	Darlington	J. Graham, Esq.	Ibid.
ɔm ε Persei to near No. 21 Persei.	Moved horizontally; it was not one meteor but separate fragments, which increased as they proceeded, until all suddenly vanished.	Highfield House.	E. J. Lowe, Esq.	Ibid.
above ε Arietis, and directly south in a line parallel with horizon.	....	Darlington near Durham.	J. Graham, Esq.	Ibid.
rpendicularly down from Polaris.	....	Highfield House, lat. 52° 57′ 30″ long. 1° 10′ W.	E. J. Lowe, Esq.	Ibid.
rpendicularly down from δ Herculis.	....	Highfield House.	Id.	Ibid.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850. Aug. 29	h m 10 7 p.m.	Greater than 2nd mag. star.	Blue............	Slight tail	Duration 1 sec.
				Curious path of a meteor. 	
	10 7 30s	= 3rd mag.	Blue............	....	Very rapid ......
30	10 39 p.m.	= to Saturn	Yellow.........	Train of sparks	Duration ½ sec.
	10 40 30s	= to Sirius	Red	No tail.........................	....
Sept. 1	9 5 p.m.	....	....	....	....
2	Evening; twilight immediately after.	= 4th mag.	....	....	1 sec. ....
	....	= 4th mag.	....	....	1 sec. ....
	10 11 12s	....	....	....	....
	10 20 p.m.	= 2nd mag.	Yellow	Left streamers...............	Duration 1 sec.
	11 13 p.m.	= 6th mag.	....	Itself as a spark	Almost instanta ous.
	11 16 p.m.	= 6th mag.	....	As a spark	Instantaneous ..
	11 17 p.m.	= 6th mag.	....	As a spark	Instantaneous ..
4	9 0 6·43	= to ♃....................	Nearly as bright as ♃; white.	Train of 5° to 6° in length	Duration 2 secs
	9 33 p.m.	= 2nd mag.	....	Train 15° long	Over 18° in 3 s
6	11 0 p.m.	....	....	....	....

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
om σ Andromedæ to nearly η Persei, when it suddenly turned at more than right angles, and fell back again towards horizon inclining E., disappearing at β Persei.	Three meteors of Aug. 29th gave a point of divergence at about H. 3 Camelopardi, and the meteor at 10^h 7^m, although at first coming from an almost opposite point, on its changing its course, if this latter motion were continued backwards, it would also give H.3.Camelopardi as the points of divergence.	Highfield House.	E. J. Lowe, Esq.	Mr. Lowe's MS.
3 Camelopardi to σ Aurigæ..	....	Ibid................	Id.	Ibid.
om ½ between γ Pegasi and χ Piscium to between η and γ Aquarii.	....	Ibid................	Id.	Ibid.
om Kockal to β Bootis	....	Ibid................	Id.	Ibid.
ross the zenith	....	Ibid................	A. S. H. Lowe, Esq.	Ibid.
down through Capric.	....	Rose Hill, Oxford.	Rev. J. Slatter.	Communicated to Prof. Powell.
down through Ophiuchus...	....	Ibid.	Id.	Ibid.
....	Meteors very numerous.	Uckfield	C. L. Prince, Esq.	B. M. S. Report.
om between Kockal and γ to ε Ursæ Majoris.	These four gave a point of divergence near β Pegasi. The three first were very small, very rapid, and appeared as if much further from the earth than usual.	Highfield House	E. J. Lowe, Esq.	Ibid.
quulei to ϑ Antinous......		Ibid................	Id.	Ibid.
quarii to β Capricorni ...		Ibid................	Id.	Ibid.
aurus-Ponitoski to β Ophiuchi.		Ibid................	Id.	Ibid.
w it commence. Little E. of γ Cephei, and nearly in a line between that star and β Cassiopeiæ, passed close to γ Cephei, and about midway between α and δ Ursæ Minoris; it disappeared midway between those stars and κ Draconis; when between α and δ Ursæ Minoris it rapidly diminished in brightness.	....	Grantham	J. W. Jeans, Esq.	Mr. Lowe's MS.
mediately below 13 Herculis, and passed 40′ W. of δ Ophiuchi.	....	Darlington	J. Graham, Esq.	Ibid.
om Pisces to Fomalhaut	....	Stone	Rev. J. B. Reade.	B. M. S. Report.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850. Sept. 10	h m 9 35 p.m.	Small	....	Train	Instantaneous ...
12	8 31 p.m.	=2nd mag.	....	Train 7° long	Over 15° in 1·5 s[ec]
	12 6 p.m.	=3rd mag.	Blue........	Streamers	Rapid ....
15	9 31 p.m.	=1st mag.	....	....	Over 25° in 4 sec
17	10 4 p.m.	....	....	....	....
21	10 18 30ˢ	Gradually increased till it was 6′ in diam.	Also in brightness until brighter than Venus when she is brightest; colour bluish, at first pale, but became gradually deeper blue.	Left a straight line of sparks; it threw off a quantity of sparks on bursting.	Moved very slo[w] and rather ir[re]gularly; pass[ed] over 7° in 6 se[c]
28	9 30 p.m.	=to Capella in brightness.	....	....	....
	10 45 p.m.	Large	Colourless ...	Left a train of light 40° in length.	Slowly ....
30	8 10 p.m.	=1st mag.	Bright	....	Very rapid .....
	....	....	....	....	....
	9 40 p.m.	=3rd mag.	....	....	Very rapid .....
	9 40 1ˢ	=3rd mag.	....	....	....
	9 48 p.m.	=1st mag.	Very bright ...	....	....
	9 50 p.m.	Small	....	....	Slow........
	10 3 p.m.	=3rd mag.	....	....	Slow........
Oct. 1	Between 9 10 p.m. and 9 30 p.m.	Ordinary	....	....	....

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
* / * * Bootis. * Arcturus.	....	Clifton	Prof. Powell.	
ear ζ Serpentarii passed midway between δ Ophiuchi and μ Serpentarii.	....	Darlington	J. Graham, Esq.	Mr. Lowe's MS.
om below α Aquilæ and moved towards W. at an angle of 65°.	Came from direction of the Dolphin.	Highfield House	E. J. Lowe, Esq.	Ibid.
° S. of Lyra, and passed close N. of ζ Herculis.	....	Darlington	J. Graham, Esq.	Ibid.
Coronæ Borealis to 4° above Saturn.	....	Stone	Rev. J. B. Reade	B. M. S. Report.
oved from a point situated in a line perpendicular to the horizon, passing through φ Ursæ Majoris (the starting-point was 2° below this star); it descended towards horizon in a direction a little E. of N. The line along which it passed subtended an angle of about 10°, with the line perpendic. to horizon, meeting that point of the meteor's path from which it started. Its disc tapered off to a point where it joined the train. It appeared like a flying-kite inverted.	....	Darlington	J. Graham, Esq.	Mr. Lowe's MS.
Draconis to γ Ursæ Majoris.	....	Stone	Rev. J. B. Reade	B. M. S. Report.
t. 45° in S.S.E., moved horizontally to S.W.	....	Highfield House	A. S. H. Lowe, Esq.	Mr. Lowe's MS.
st below Polaris to Cassiopeia	....	Castle Donington	W. H. Leeson, Esq.	E. J. Lowe.
ar α Lyræ	....	Ibid...............	Id.	Ibid.
om midway between Cassiopeia and Delphinus to midway between Delphinus and Altair.	....	Ibid...............	Id.	Ibid.
om midway between Delphinus and Altair, in a vertical direction; path about 10°.	....	Ibid...............	Id.	Ibid.
om α Capellæ towards Polaris, in an upward direction.	....	Ibid...............	Id.	Ibid.
om α Lyræ perpendic. down.	....	Ibid...............	Id.	Ibid.
Pegasi towards horizon	....	Ibid...............	Id.	Ibid.
ree meteors at different times during the Aurora Borealis were seen to shoot from the arch, not passing through it, but emerging from it; their paths seemed irregular. The first shot out from near the Pleiades and made for the horizon; the second darted out about the meridian and took an oblique path south; the third was in the west and fell towards the horizon.	....	Observatory, Durham.	R. C. Carrington, Esq.	Private report to E. J. Lowe.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850.	h m				
Oct. 1	9 44 3^s	As a spark, but = to ♃.	Orange	No tail	Duration ½ sec.
5	6 30 p.m.	Same size			
	6 45 p.m.				
	7 0 p.m.	Small			Rapid
	7 35 p.m.	=3rd mag.			Rather slow
	7 40 p.m.	=3rd mag.			Rapid
	10 10 p.m.	Small			
	10 15 p.m.	Small			
	10 28 p.m.	=3rd mag.			Over 10° in 1·3 s
	10 40 p.m.	=3rd mag.			Over 8° in 1 sec.
7	10 15 p.m.				
9	9 30 p.m. (G.M.T.)	Two			Two or three se
	10 30 p.m.	Small			
	10 45 p.m.	Small			
		Larger than a cricket-ball [?].	Blue, very bright.	A well-marked line of light	Slow
		Several shooting stars			
10	9 45 p.m.	=2nd mag.			Over 20° in 3 se
11	9 23 p.m.	Four			Short
	10 0 p.m.	Small			
13	6 0 p.m.	Brilliant meteoric ball	Threw the stars into shade.	Burst with various colours	Instantaneous
15	11 5 p.m.	=2nd mag.	Blue	Left a mass of light; blue	Duration ½ sec. 
26		One as large as Venus			
28	7 50 p.m.		Reddish	Long tail of light, and sparks.	Duration 3 secs.
	9 26 p.m.	=3rd mag.			Over 15° in 2 se
Nov. 1	7 20 p.m.	As a spark, appearing to be quite low in the air.	Yellow	No accompaniment	Duration 1 sec.
2	6 20 p.m.	Small			Time 1 sec.
	6 25 p.m.	Small			Rapid
	6 35 p.m.	=3rd mag.			Rapid
	6 38 p.m.	Very brilliant		Train	Rapid
	6 51 p.m.	=3rd mag.			Slow

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
m γ Pegasi at an angle of 5° towards S. Had the appearance of being near me. urora Borealis at the time.	Circular though as a spark; disappeared at an altitude of 15°.	Nottingham......	E. J. Lowe, Esq.	Mr. Lowe's MS.
m N.W. to S.E.	Did not explode; frequent lightning.	Hereford	Correspondent...	Hereford Times.
m ζ Ursæ Majoris perpen-icularly towards horizon; st in clouds.	......	Castle Donington.	W. H. Leeson, Esq.	Mr. Lowe's MS.
m β to μ Ursæ Majoris	......	Ibid.	Id.	Ibid.
m ϵ Bootis to Arcturus	......	Ibid.	Id.	Ibid.
aris to ζ Ursæ Majoris	......	Ibid.	Id.	Ibid.
m α to ϵ Arietis	......	Highfield House	E. J. Lowe, Esq.	Ibid.
lromeda to Cassiopeia	......	Hartwell Rectory	Rev. C. Lowndes	Ibid.
Lyncis, about 2° of δ Urs. Iaj.	......	Darlington	J. Graham, Esq.	Ibid.
n κ towards μ Ursæ Majoris	......	Ibid.	Id.	Ibid.
siopeia to Capella	......	Hartwell Rectory	Rev. C. Lowndes	Ibid.
n above Aries under An-rom.	......	Rose Hill, Oxford.	Rev. J. Slatter.	
45° in W.S.W.	......	Highfield House	A. S. H. Lowe, Esq.	Ibid.
ast	......	Ibid.	Id.	Ibid.
45° in N.W., moved to-ards the N. nearly horizon-ally, but inclining slightly arthwards.	Exploded into half-a-dozen large sparks.	Hereford	C. Lingen, Esq.	H. Lawson, Esq.'s letter to E. J. Lowe.
......	With a faint Aurora	Huggate, near Pocklington, Yorkshire.	Rev. T. Rankin.	Letter to Prof. Powell. See Appendix, No. 8.
sed 2° E. of ϵ Cygni, and 3° . of the cluster in Delphinus.	......	Darlington	J. Graham, Esq.	Mr. Lowe's MS.
down from left-hand of ootes.	......	Rose Hill, Oxford.	Rev. J. Slatter.	
n zenith to the north	......	Highfield House	A. S. H. Lowe, Esq.	Ibid.
n zenith about half-way to orizon.	......	Toronto, Canada	Correspondent...	Globe, Oct. 19, 1850. See Appendix, No. 6.
n half-way between e and η agittæ through γ Sagittæ, hen it turned, rose and ex-oded near β Cygni.	It passed behind several clouds. The accompanying diagram will best show the curious path.	Highfield House	E. J. Lowe, Esq.	Mr. Lowe's MS.
n Orion to W.	Several	Trowbridge	C. J. Astley, Esq.	B. M. S. Report.
r zenith moved nearly hori-ontally, with slight dip in a .E. direction, disappearing ightly E. of Limerick.	......	From Galway to Limerick, in coach (8 miles from Limerick).	J. W. Kelly, Esq.	Ibid.
ough No. 27, and 1° E. of o. 11 Lyncis.	......	Darlington	J. Graham, Esq.	Mr. Lowe's MS.
ed over 10° of space; pass-l 30^s under α Pegasi.	Nearly horizontal, inclining slightly downwards, moving towards S.W.	Highfield House	E. J. Lowe, Esq.	Ibid.
sæ Majoris perpendic. down	......	Castle Donington	W. H. Leeson, Esq.	Ibid.
sæ Majoris to γ Bootis	......	Ibid.	Id.	Ibid.
kab to Mirach	......	Ibid.	Id.	Ibid.
ma Coronæ Borealis per-endic. down.	......	Ibid.	Id.	Ibid.
ræ to Gemma	......	Ibid.	Id.	Ibid.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850.	h m				
Nov. 2	6 54 p.m.	Small	....	....	Slow............
	6 58 p.m.	Small	....	....	Slow............
6	7 0 p.m.	Intensely bright, and large meteor.	....	After bursting, a streak of light remained for about 20 minutes, 10° or 12° in length, with a bright nucleus at one end, like a comet; decreased in length and vanished.	Shot rapidly fr N.W. to S.E. about 3 secs.; noise.
8	9 35 p.m.	=3rd mag.	....	Train	Over 9° in 1·5 s
	9 57 p.m.	=4th mag.	....	....	Over 10° in 1 se
	10 0 p.m.	=3rd mag.	....	Train	Over 6° in 3 sec
9	....	....	....	....	....
10	8 0 p.m.	....	....	....	Visible 10 secs. last suddenly appeared.
12	5 50 p.m.	....	....	....	Duration 1 sec
13	5 45 p.m.	Larger than ♀	Bright and bluish.	No explosion	....
	6 12 p.m.	Large	....	....	....
	7 5 p.m.	About = ♀	Bright yellow..	....	....
14	5 to 6 a.m.	38 meteors (only a portion of the sky visible).	Light on combustion; seemed to increase as they descended.	Disappeared with faint explosion.	....
	5 45 a.m.	Brilliant meteor	=twice ♃ ...	Tail 3° long; light became pale red and then disappeared.	About 6 secs.
15	5 to 6 a.m.?	16 small meteors	....	....	....
16	....	....	....	Disappeared; no explosion	....
19	....	....	....	....	....
23	10 55 p.m.	3 times larger than Saturn.	Yellow	Slight tail	Rapid ....

* Mr. Leeson gives G.M.T. His lat. and long. a

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
...l towards α Ceti	....	Castle Donington	W. H. Leeson, [Esq.*	Mr. Lowe's MS.
...kal to δ Aquarii	....	Ibid.	Id.	Ibid.
...n about 60° alt. passed ...ithin 10° N. of ♀; at about ...3° alt. burst into stars of ...rilliant colours.	....	Bombay: Malabar Hill.	A correspondent to Bombay Times.	Bombay Bimonthly Times, Nov. 15. Communicated by Dr. Buist. See Appendix, No. 15.
...ed from half between μ and ... and passed 2° below ϵ Ge...inorum.	....	Darlington	J. Graham, Esq.	E. J. Lowe.
...ough southern confines of ...agitta and towards α Aquilæ.	....	Ibid.	Id.	Ibid.
...n 4° N. of β, and passed ...hrough No. 3 Aquarii.	....	Ibid.	Id.	Ibid.
...eral in all directions	....	Trowbridge	F. J. Astley, Esq.	B. M. S. Report.
... sky was clouded. Suddenly ... very luminous appearance ...resented itself, as seen ...hrough the clouds. The ...ght was lenticular-shaped; ...s base rested on the hori...n a little E. of S., the mid...e part being from 5° to 10° ... E. of that point. Its ...readth at base was 4°, the ...titude of its apex (which ...ppeared to be perpendicular ... its base) was about 30°. ...he brightest part was the ...ntre of the base, and the ...ght shaded off gradually to ...e edges. This probably was ... large meteor.	....	Darlington	J. Graham, Esq.	Mr. Lowe's MS.
...S.E., half-way to zenith...	Overcast, a brilliant vivid flash; could it be a meteor?	Highfield House.	E. J. Lowe, Esq.	Ibid.
...n zenith towards horizon in ...W.; lost behind clouds.	....	Oxford	....	Statements made to Prof. Powell.
...n the zenith perpendicularly ...own, in N.W.	....	Beeston Railway Station ($1\frac{1}{4}$ mile S. of Highfield House).	J. Watson, Esq.	Mr. Lowe's MS.
...n zenith towards N.W.	....	Oxford.		
...n E. to W.	Wind E.; supposed by observer to influence the motion of the meteors.	India: Bore Ghaut.	A correspondent to Bombay Times.	Bombay Times, Nov. 20. Communicated by Dr. Buist. See Appendix, No. 16.
... to S.E.	....	Ibid.	Id.	Ibid.
....	....	Ibid.	Id.	Ibid.
... to N.E.	....	Bombay	Correspondent to Dr. Buist.	See Appendix.
...l to N.W.	....	Ibid.		
...n half between δ and ϵ to ϑ ...ti.	Circular, well-defined disc.	Highfield House	E. J. Lowe, Esq.	Mr. Lowe's MS.

...52° 51′ 23″·75 N. Long. 1° 18′ 42″ W.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850.	h m				
Nov. 28	9 38 p.m.	=4th mag.	....	....	Over 6° in less]
	9 43 p.m.	=5th mag.	....	....	Over 10° in 1 s
	9 47 p.m.	=3rd mag.	....	Train 5° long	Over 10° in 2 s
	10 10 p.m.	4 times size of Jupiter	Colour of Jupiter.	....	Very slowly....
	10 30 p.m.	Large meteor	....	....	....
		Very large	....	Train of light	....
		Very large	....	Train of light	....
29	7 30 p.m.	Meteor bright = twice ♀.	White or bluish.	Left brilliant; train visible through whole track for 6 secs.: no explosion.	Velocity mode
	7 45 p.m.	Fine meteor............	Blue............	Long light tail, visible for some time.	....
		Fine meteor............	Blue............	Ditto	....
	8 43 p.m.	=4th mag.	Yellow	Slight tail	Rapid ....
	9 0 p.m.	Large	Very bright, seen in-doors with candles.	....	....
	10 35 p.m. (G.M.T.)	Fully = ½ diam. of ☾, or 10′ of arc.	Most dazzling	A glow of light continued, after the meteor had vanished, for some little time.	Either statio or else appr ingmeinastr line some 4 secs., and a time shone from behi cloud.
	11 30 p.m.	Bright	....	....	....
		Large	Very bright, seen in-doors with candles.	....	....
30	5 0 a.m.	....	....	....	....
	....	....	....	Heard to explode	....
Dec. 3	....	Large	....	....	....
4	9 33 p.m.	=3rd mag.	....	....	Over 10° in 1
5	11 20 p.m.	Large	Blue............	....	Duration 3 se
		About = ♀	....	Little train	Velocity mod

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
ough ι towards No. 12 Tauri	....	Darlington	J. Graham, Esq.	Mr. Lowe's MS.
ough α, and about 1° S. of Tauri.	....	Ibid.................	Id.	Ibid.
m a point 4° W. of, and of me alt. as α Ceti; α passed idway between Saturn and Ceti.	....	Ibid.................	Id.	Ibid.
m near Aldebaran perpendic. own over the space of 30°.	....	Highfield House	A. S. H. Lowe, Esq.	Ibid.
....	....	Oxford	Mr. G. A. Rowell	Communicated to Prof. Powell. Appendix, No. 7.
n Major to Orion	....	Trowbridge	F. J. Astley, Esq.	B. M. S. Report.
ris to Pleiades	....	Ibid.................	Id.	Ibid.
ly perpendicularly down rough about 15° in W.; sappeared between α and γ quilæ.	....	Oxford	Mr. G. A. Rowell	Communicated to Prof. Powell. Appendix, No. 7.
m E. to N.W.	....	Worthing, Sussex	A. H. Lowe, Esq.	Letter to E. J. Lowe.
....	....	Edinburgh	Correspondent...	Ibid.
m γ Draconis downwards to- ards W. at an angle of 60°.	....	Highfield House	E. J. Lowe.	
cended nearly perpendicu- rly in W.	....	Oxford	Mr. G. A. Rowell	Communicated to Prof. Powell. Appendix, No. 7.
....	Afterwards it came out in a break in the clouds, and was most brilliant for a few seconds.	Mr. Bishop's Observatory, Regent's Park.	J. R. Hind, Esq., F.R.S.	Letter to E. J. Lowe.
m Orion towards Polaris ...	....	Jersey	Rev. S. King ...	B. M. S. Report.
m W. to E., nearly horizontal	....	Oxford	Mr. G. A. Rowell	Communicated to Prof. Powell. Appendix, No. 7.
....	One of our labouring men reported there was quite a shower of meteors for some time; he never saw so many.	Highfield House	Thomas Cox (a farming man).	Mr. Lowe's MS.
....	Meteoric stone fell, 3 feet circumference; dug up immediately.	Bengal	....	See Appendix, No. 18.
m W. to Arcturus	....	Trowbridge	F. J. Astley, Esq.	B. M. S. Report.
ough κ 2 Tauri and about 2° of Aldebaran.	....	Darlington	J. Graham, Esq.	E. J. Lowe.
pendicularly down in E.S.E.	....	Highfield House	S. Watson, Esq.	Mr. Lowe's MS.
m 6° to 8° E. of ♄ nearly perpendicularly down but a little towards E., though nearly °, then disappeared.	....	Oxford	Mr. G. A. Rowell	Communicated to Prof. Powell. Appendix, No. 7.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1850. Dec. 6	h m 9 33 p.m.	=2nd mag.	....	Train fully 15° long	Over 25° in 3
8	....	Middle size	....	Burst into shower of sparks	Nebulosity of sp for some seco
9	....	Large, =4 times 1st mag.	....	Tail *fan-shaped*; length about double diameter of body; separated into sparks.	....
12	6 0 p.m.	....	....	Long train	....
	9 20 p.m.	=2nd mag.	....	....	Over 10° in 1 s
	9 32 p.m.	=2nd mag.	....	....	Over 6° in 3 s
	9 37 p.m.	=3rd mag.	....	....	Over 9° in 1·5
13	11 40 p.m.	As a spark	Orange-red	Sparks followed it	Instantaneous
24	9 30 p.m.	=2nd mag.	Yellow	No accompaniment	Duration 4 sc motion slow
26	9 35 p.m.	=4th mag.	Blue	Tail	Duration ½ se
	10 30 p.m.	Small	....	....	....
		Small	....	....	Rapid
	10 31 p.m.	Small	....	....	Rapid
	10 40 p.m.	=5th mag.	Colourless	Continuous tail	Duration $\frac{1}{10}$ s
28	7 38 p.m.	Large	Bright; no decrease or increase.	Sparks	Rapid
1851. Jan. 5	6 30 p.m.	=3rd mag.	....	....	Over 6° in 3 s
	6 53 p.m.	=2nd mag.	....	....	Over 8° in 1
	7 1 p.m.	=4th mag.	....	....	Over 8° in 2 s

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
...sed through o 2 Orionis, 47 ...auri and about 1° above κ 2 ...eti.	....	Darlington	J. Graham, Esq.	E. J. Lowe.
....	....	Sherapore, Deccan.	Correspondent to Dr. Buist.	See Appendix, No. 17.
...eared in tail of Ursa Major, ...oved parallel to the body, ...en curved below the ...ointers; disappeared about ...0° alt. towards N.E.	....	Huggate, Pocklington, Yorkshire.	Rev. T. Rankin...	Letter to Prof. Powell. Appendix, No. 8.
...eti to Fomalhaut	....	Hartwell	Rev. C. Lowndes	E. J. Lowe.
...sed 1° below ζ and o Tauri, ...d ½ way between α and 2 Ceti.	....	Darlington	J. Graham, Esq.	Ibid.
...eared near Sirius; its path ...as nearly perpendicular to ...orizon, but formed a some...hat greater angle with hori...on W. than S.; the meteor ...isappeared when 5° E. of ...irius.	....	Ibid................	Id.	Ibid.
...ough γ Orionis, and above η ...rionis, passing that star at ...st. of 3° 30′.	....	Ibid................	Id.	Ibid.
...n between α and β Gemi...orum.	Fell nearly perpendicularly down, inclining slightly to N.	Highfield House	E. J. Lowe.	Ibid.
...mmenced 20° above the W. ...orizon, passed through the ...enith and through the Twins, ...isappearing suddenly in E. at ...n altitude of 30°; ill-defined ...sc.	....	Ibid................	Id.	Ibid.
...m κ Ursæ Majoris to ½ be...veen Castor and Pollux.	Moved horizontally	Ibid................	Id.	Ibid.
..., in S.W.	....	Ibid................	A. S. H. Lowe, [Esq.	Ibid.
...n alt. of 45° in W.	Fell perpendicularly down.	Highfield House	E. J. Lowe	Ibid.
...n alt. of 45° in S.W.	Nearly perpendicularly down, inclining to S.	Ibid................	Id.	Ibid.
...m γ to ξ Ursæ Majoris	Ill-defined, darted rapidly.	Ibid................	Id.	Ibid.
... .	Parallel to Milky Way and brilliant.	St. Ives, Huntingdonshire.	J. King Watts, Esq.	Communicated to Prof. Powell.
...m a point 3° below a straight ...ne joining Erica and α Pe...si, about ½ between those ...ars, and moved S. in a direc...on nearly parallel with that ...ne, but tending slightly to...ards the horizon.	....	Darlington	J. Graham, Esq.	Mr. Lowe's MS.
...way between φ 2 and φ 3 ...eti, and passed 2° 30′ S. of ...Ceti.	....	Ibid................	Id.	Ibid.
...sed from a point in a straight ...ne joining α and 45 Ceti, ...bout 1° nearer the former ...ar, and passed 2° above τ Ceti.	....	Ibid................	Id.	Ibid.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1851.	h m				
Jan. 5	7 39 p.m.	=5th mag.	....	....	Over 3° in less ½ sec.
8	8 9 a.m.	Seen in bright sunshine.	Brilliant coloured ball.	Burst into numberless sparks.	....
10	....	= ♀	Red	Train of crimson sparks vanished; no explosion.	....
16	3 15 p.m.	=2 ♀	....	Long white train; no explosion.	....
21	10 23 p.m.	=4th mag.	Yellow	No tail	Rapid
	10 28 p.m.	=1st mag.	Blue	Pale train	Rapid
22	....	....	....	....	....
23	10 13 p.m. (G.M.T.)	=3rd mag.	....	No train	....
	....	....	....	....	....
27	....	....	....	....	....
31	13 7 p.m.	....	Red	....	....
Feb. 3	10 15 p.m.	=2nd mag.	Yellow	....	Duration ½ sec
		=2nd mag.	Yellow	Train	Duration 0·5 s
4	10 40 p.m.	=to Venus	Pale colour ...	No tail	Slowly
6	9 0 p.m.	=to Sirius	Yellow	No tail	Rapid
8	10 39 p.m. (G.M.T.)	>Sirius	....	No train	1 sec.
16	7 30 p.m.	Night	....	Violet train	....
24	10 p.m.	= ♃	....	....	....
Mar. 11	Day break..	Brilliant, full	....	Train	Loud noise, a ed close.
	....	....	....	....	....
13	....	....	....	....	....
21	10 30 p.m.	Small	....	....	....
22	8 0 p.m.	Small, spark-like	....	....	....
	8 26 p.m.	Large	As bright as δ Leonis, and of a *dull red*.	Train of light	Duration 2 s
26	7 45 p.m.	3rd mag.	Bright and white.	None	Rather slow.
30	....	....	....	....	....
April 1	....	....	Brilliant	....	....
2	9 51s Grantham Time.	=to ♃	As bright as ♃, rather more blue.	Train of light	Duration u secs.

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
ed above Sirius at a distance 4°, moved southward, parlel with horizon.	....	Darlington	J. Graham, Esq.	Mr. Lowe's MS.
....	Black mass fell ...	Beerbhom, India	Correspondent to Dr. Buist.	See Appendix, No. 19.
y N.	....	Bombay	....	Ibid. No. 20.
y S.	....	Ibid.......	....	Ibid. No. 21.
n Pleiades to *e* Tauri	....	Highfield House	E. J. Lowe, Esq.	Mr. Lowe's MS.
n No. 22 Monocerotis	Downwards	Ibid................	Id.	
....	Meteor...............	Bedfordshire ...	Mr. Maclean ...	B. M. S. Report.
n alt. 80° in S. to alt. 15° om N.E. to S.S.W.	....	Rose Hill, Oxford	Rev. J. Slatter...	MS.
....	Meteor...............	Ibid................	Id.	B. M. S. Report.
....	Meteor...............	Uckfield	C. L. Prince, Esq.	Ibid.
n zenith through Leo	During Aurora Borealis.	Highfield House	E. J. Lowe, Esq.	Mr. Lowe's MS.
uri to *α* Ceti...............	....	Cardington, Bedfordshire.	— Maclean, Esq.	Ibid.
e from direction of Pleiades; d started from *ζ* Tauri, d moved to *α* Ceti.	....	Highfield House	E. J. Lowe.......	Ibid.
n *γ* Cancri 35° perpendicuYly down.	....	Ibid................	A. S. H. Lowe, Esq.	Mr. Lowe's MS.
n *δ* Eridani perpendicularly wn.	....	Ibid................	E. J. Lowe, Esq.	
n below *β* Urs. Maj. through Draconis almost to hoion.	....	Rose Hill, Oxford	Rev. J. Slatter...	MS. com.
cally down from Bootes, m alt. 15° to 5°.	....	Huggate, near Pocklington.	Rev. T. Rankin...	Letter. See Appendix, No. 26.
....	....	Bombay	Correspondent to Dr. Buist.	Appendix, No. 22.
....	....	Caffraria; Lat. 30° 40′ S., Long. 27° 30′ E.	Lieut. Gawler ...	Appendix, No. 30.
....	Meteor...............	Uckfield	C. L. Prince, Esq.	B. M. S. Report.
....	Meteor...............	Thame, Oxon ...	W. Johnson, Esq.	Ibid.
N.E.	....	Highfield House	A.S.H.Lowe,Esq.	Mr. Lowe's MS.
....	Many	Grantham, Linc.	J. W. Jeans, Esq.	Ibid.
8 Can.-Venatici; took a newhat wavy course tords *α* Leonis; when nearly r *δ* Leonis it disappeared 5° or 6°, then reappeared same colour; it finally disbeared at Regulus.	....	Ibid................	Id.	Ibid.
....	Issued from Pleiades.	St. Ives, Hunts..	J. King Watts, Esq.	Communicated to Prof. Powell.
....	Meteor...............	Thame, Oxon ...	W. Johnson, Esq.	B. M. S. Report.
....	....	Aden	Correspondent to Dr. Buist.	See Appendix, No. 10.
γ Cephei, took a downward rse, passed over *i* Cephei, ow diminished in brights, and disappeared 5° to 6° ow *i* Cephei.	....	Grantham, Linc.	J. W. Jeans, Esq.	Mr. Lowe's MS.

Date.	Hour.	Appearance or magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1851. April 5	h m 8 26 p.m.	= 4th mag. star until it passed 20 Argûs Navis, when it increased and surpassed ♃.	Rather bluer than ♃.	At first a single line of sparks; afterwards an increasing number of lines.	Duration 2·5 sec; vanished suddenly.
18	8 53 p.m.	= to Procyon	= to Sirius; orange-red.	Abundance of streams, which rapidly vanished.	Duration 0·5 sec.
19	During half hour about 10 p.m.	Numerous meteors; some = ♀ or ♃; most small.	....	....	....
20	....	Meteoric shower......	....	....	....
24	10 20 p.m. (G.M.T.)	Gradually brightening till = 1st mag.	....	No train	....
27	10 o'clock	A splendid meteor ...	....	....	....
	10 5 p.m. (G.M.T.)	$\frac{1}{4}$ size of ☾	Intense; it was surrounded by rich purple fading into blue, then much orange, and lastly light yellow.	A considerable train of light yellow light.	From 4 secs. to [illegible] secs.
	10 5 p.m. (G.M.T.)	(Account similar to that above.)	....	....	....
	10 5 p.m. (G.M.T.)	$\frac{1}{4}$ size of ☾	So brilliant, that distant objects were as distinct as in the day.	When it burst sparks were seen to drip from it.	....
	10 5 p.m. (G.M.T.)	....	Bright blue when it burst; compared to that of a lucifer match.	Sparks very blue...........	....
	10 5* p.m. (G.M.T.)	not = $\frac{1}{3}$ ☾	= $\frac{1}{3}$ of ☾'s. Bluish red; did not increase or diminish.	Continuous train left behind; the meteor broke into sparks.	3 secs. ....
	10 5 p.m. (G.M.T.)	Nearly $\frac{1}{4}$ full moon, illuminating the whole horizon, like daylight.	Surrounded by a rich purple light, succeeded by blue, orange and yellow.	Yellowish train, disappeared in sparks; no noise.	Velocity consi[derable], viz. 4 secs.

* 10^h 5^m was the exact G.M.T., although at Oll

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
m 29 Monocerotis, near 20 rgûs Navis, to α Pyxis-nau-cæ; it disappeared instantly n attaining its maximum rightness; point of first ap-earance Æ. 8^h 1^m, N.P.D. 9° 33′; point of disappear-nce Æ. 8^h 36^m, N.P.D. 9° 14′.	....	Highfield House	E. J. Lowe, A. S. H. Lowe, Esq., and S. Watson, Esq.	Mr. Lowe's MS.
n ε Hydræ, 7° perpendicu-rly downwards.	Aurora Borealis at the time.	Highfield House	E. J. Lowe, Esq.	Ibid.
....	....	Bombay and Co-lapoor.	[Dr. Buist.	[No. 24.
....	Same as last?	Caunpoor.........	Correspondent to	See Appendix,
n 30′ below Capella, nearly β Aurigæ.	....	Rose Hill, Oxford	Rev. J. Slatter...	MS.
n E. to W......................	....	Gainsborough ...	Nottingham Journal.	Correspondent.
en first seen alt. 70° in .N.W., and moved gradu-ly towards N., disappear-g nearly due north.	Suddenly a blaze of soft yellow light overspread the country; the light seemed to fall gently on the ground and to run along it; lis-tened for sound of explosion, but heard none.	Durham	A friend of Rev. Prof. Cheval-lier.	Prof. Chevallier's letter to E. J. Lowe.
....	....	Bishopwear-mouth.	Correspondent...	Ibid.
peared near the zenith in .W., and moved towards N. robably it was nearer the nith than at Durham).	Very favourably seen from a hill side; no noise heard, although listened for, for a few minutes.	Esh	Id.	Ibid.
.E. moving to N.W.........	....	Alden Grange (2 miles W. of Durham).	Id.	Ibid.
attracted by a light; on rning round it was seen ar 1 and 2 Cassiopeiæ, ssed through σ, and ended ξ Cassiopeiæ. Positions en first seen, Æ. 23^h 30^m, P.D. 32°; when it exploded, . 0^h 20^m, N.P.D. 50° 40′.	The fragments when it burst were prismatic; no noise was heard though listened for.	Beeston (is 1 mile exactly S.W. of Highfield House).	Rev. M. H. Ricketts.	Mr. Lowe's MS.
t first about 70° in W.N.W. oving towards N.; another server saw it first in S.E., en moved to N.W.	....	Durham and neighbour-hood.	Several observers	Communication to Prof. Chevallier. Appendix, No. 9.

given at 10^h 30^m, and Gainsborough 10^h.

Date.	Hour.	Appearance or Magnitude.	Brightness and colour.	Train or sparks.	Velocity or duration.
1851. April 27	h m 10 5 p.m.	Brilliant	Like a ball out of a Roman candle.	....	....
	10 10p.m.± (G.M.T.)	Large meteor, pear-shaped.	Brightness = morn. nearly.	No train	3 secs. ....
	10 30 p.m.	Large as a cricket-ball [?	Light = ☾ ...	Large stream of fire	30 secs. ....
29	10 0 p.m.	Small	....	....	....
May 8	10 20 p.m.	Large meteor	Brilliant and white.	None	Rapid ....
28	10 18 30s	=2nd mag. star	=2nd mag.; colour white.	Behind it left a streak, which disappeared almost instantaneously.	Duration 3 secs.
29	10 3 p.m.	Large meteor	White	None	Rapid ....
31	10 40p.m.± (G.M.T.)	=4th mag.	Red	No train	....
June 2	10 35p.m.± (G.M.T.)	=4th mag.	....	....	....
20	11 30 p.m.	Large fire-ball........	....	Leaving a thread of light..	3 or 4 min.; dis pated slowly.
22	9 30 p.m.	Ball nearly = ☽	Whitish red; appeared near.	Waving luminous streaks remained after disappearance.	7 minutes ......
	11 p.m.	Brilliant fire-ball......	....	Stream 60° long	....
26	9 40 p.m.	=1st or 2nd mag. ...	....	Continuous train of light..	Slowly; 1 sec.
July 2	9 35p.m.± (G.M.T.)	=2nd mag.	....	....	½ sec. ....
	9 35p.m.± (G.M.T.)	=2nd mag.	....	Scintillation..................	....

Direction or altitude.	General remarks.	Place.	Observer.	Reference.
...om S.E. towards N.W., horizontally.	....	Nottingham, near Trent Bridge.	W. B. Carter, Esq.	MS. of E. J. Lowe.
...all elevation from N. to N.W.	....	Near Oxford ...	Statement to Rev. J. Slatter.	MS.
...om N.E. to N.W...............	Soon exploded with a hissing noise.	Ollerton	Correspondent...	Nottingham Review.
...rpendicularly down in S.W.	....	Highfield House	A.S.H.Lowe,Esq.	Mr. Lowe's MS.
...W..............................	Issued from below Jupiter and near him.	Saint Ives, Hunts	J. King Watts, Esq.	Communicated to Prof. Powell.
...om χ through β, between γ and δ (being 30^s dist. of δ), 1° E. of ι, 1½° E. of ζ, fading away near and to N. of η Ursa Majoris.	Moved over a great space, perpendicularly *upwards*. Point when first seen, Æ. X^h 2^m, Dec. 48° 30′ N.; point of disappearance, Æ. XIII^h 14^m, Dec. 51° N.	Beeston (1 mile S.W. of Highfield House).	E. J. Lowe, Esq.	Mr. Lowe's MS.
...S................................	Issued from between two clouds and had a singular appearance by falling perpendicularly down the face of a dark cloud until it vanished.	Saint Ives, Hunts	J. King Watts, Esq.	Communicated to Prof. Powell.
...om near β Ophiuchi to 12° W. of η Ophiuchi.	....	Rose Hill, Oxford	Rev. J. Slatter...	MS.
...ross claws of Scorpio	....	Ibid...............	Id.	Ibid.
...om Delphinus to Ursa Maj....	Rounded on the advancing side.	Kilkenny House, Bath.	Lieut. R. W. H. Hardy, R.N.	See Appendix, No. 28.
...om W. to E.	Assumed a dispersed form, threw out red balls and disappeared.	Belfast	J. Cameron, Esq.	Letter. See Appendix, No. 31.
....	....	E. part of London	W. Frost, Esq....	Letter. See Appendix, No. 30.
...wnwards at 45° to S.; from Arcturus through 20°.	....	Highfield House, Nottingham.	E. J. Lowe, Esq. and F. E. Swann, Esq.	Communicated by Mr. Lowe.
...5 E. of Altair to 10° below it	....	Rose Hill, Oxford	Rev. J. Slatter...	MS. com.
...3E. of Altair to about 10° below it.	....	Ibid...............	Id.	Ibid.

APPENDIX,

Containing details from the original Communications of the above Observations made to Prof. Powell.

No. 1.—Note from Mrs. Dixon.

A Meteor seen at Ventnor, Isle of Wight, Monday, September 4, 1848, *about* 9 *o'clock* P.M.—"I was sitting out of doors when the whole view was suddenly illuminated as brightly as by the full moon, the light being rather lurid. On looking S.W. by W. at the altitude of about 50°, I saw a vivid ball of fire about two-thirds the diameter of the moon, just bursting vertically in half, scattering bright sparks of various sizes in all directions, and one large body, about one-third the size of the whole meteor, fell rapidly towards the earth, bearing a little south, leaving a luminous track. As it fell it became less bright and defined; when it had fallen about 25° it again burst, scattered itself, and was dissipated: three minutes at least must have elapsed before the luminous track and ali the bright sparks had disappeared. I heard much the same account of the meteor as seen in Hampshire, nearly forty miles to the west, and in Sussex, forty miles to the east of Ventnor.

"On the same evening there were several falling stars in other parts of the heavens, more (as far as I remember) to the south, but I have no memorandum of the point of the compass.

"A Dixon."

No. 2.—A Letter to Prof. Powell from E. J. Lowe, Esq.

"My dear Sir,—Mr. Lawson has been kind enough to forward the following account of a meteor seen by W. H. Weekes, Esq., at Sandwich, in Kent, of which I send you these particulars.

"Yours truly,

"E. J. Lowe.

"'1850, February 5, 6^h 50^m (clock time). My attention being fixed upon Orion (a greyish haze prevailing at the time), I observed a speck of dull light commence at a point little west of that splendid group of stars, at an altitude of 28° 30′ above the horizon. The light went on increasing rapidly in magnitude and intensity, continuing stationary the while, and glowing through the thin grey mist like a moderately red-hot iron ball, until it had acquired an apparent diameter equal to at least one-third that of the full moon, when, without any noise of an explosion being heard, it suddenly burst, the main body taking a slow rectilineal motion parallel to the horizon and to the eastward; the instant when the motion of the meteorolite commenced many large, glowing, red fragments were thrown off in various directions from the centre, and a brilliant shower of variegated fire descended perpendicularly towards the earth. So beautiful was it that it resembled the coloured rain from a sky-rocket.

"'The following characteristics are remarkable:—

"'1st. It formed, or at least appeared gradually, at a stationary point in the sky, and from the moment it first became visible, until it burst and took motion, the period was 1 minute 45 seconds.

"'2nd. The motion of its main body was so deliberate that it lasted 45 secs.

"'3rd. At the place of its gradual formation the appearance of a luminous disc, equal to 1° in the heavens, was left after it took flight, which luminous disc, with the line of its flight to the eastward, and also the course of its descending coloured rain, though all of them, gradually decreasing, continued visible fully 3 minutes after the primary body had disappeared.'

"Perfect reliance may be placed on these observations, and especially on the duration of time elapsed between each feature, as Mr. Weekes has been accustomed to count seconds in his astronomical observations."

No. 3.—Note from Mrs. Smyth to Prof. Powell.

"Port Madoc, Carnarvonshire, ♂ 13th Aug. 1850.

"About a quarter past 11 P.M., looking eastward, we saw a meteor rush horizontally towards the south, leaving a long bright streak behind it.

"First seen below β Aquilæ and ended above Fomalhaut.

"The Pleiades had just risen above the peak of Cynicht to the N.E. The night was splendid. "A. S."

Note to Capt. Smyth. "Collingwood, 16th August, 1850.

"Of 75 meteors we saw in about an hour or an hour and a half, on the night of the 9th, only 4 or 5 did not emanate from a point somewhere near β Camelopardali. It clouded, and the 10th was bad."

No. 5.—Letter to Prof. Powell from Mr. Boreham.

"Haverhill, Aug. 17, 1850.

"Dear Sir,—I beg to forward you a rough diagram, made by Mrs. W. W. Boreham on the night of the 11th of August, of the approximate paths of 55 shooting stars observed by her from $9^h\ 15^m$ till 11 o'clock on that evening.

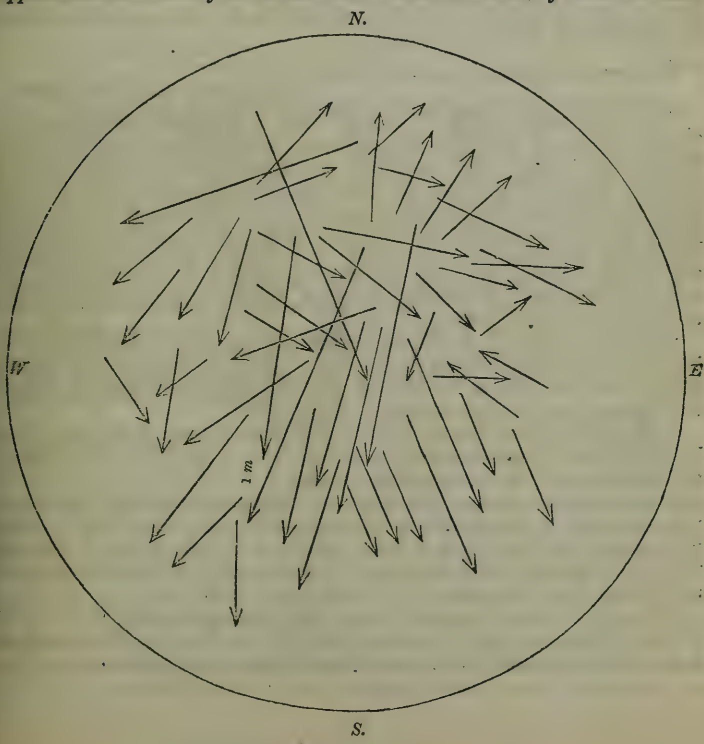
"Forty were observed on the night of the 9th from $9^h\ 30^m$ to 11 o'clock.

"The course of that headed 1 *m* ought to have been placed a little more westward, but I send the diagram uncooked.

"I am, dear Sir, yours most truly, WM. W. BOREHAM."

"*Rev. Prof. B. Powell, &c. &c., Oxford.*"

Approximate directions of 55 Meteors observed at Haverhill, by Mrs. Boreham.



No. 4.—Letter to Prof. Powell from Rev. J. Irwin.

"Vicarage, Steeple Claydon, Aug. 20, 1850.

"Sir,—In reply to your communication, I beg to say that the shower of shooting stars I saw on the night of the 12th of August, at about 20 minutes before 12, was not in the *south-western*, as misprinted in the 'Times,' but in the south-eastern horizon, a little to the eastward of south. I was walking home with some friends on that night, and our attention was attracted by the beauty and brilliancy of several of these meteors, which we observed, each exclaiming 'How beautiful! I never saw anything like that;' but, a the period I have mentioned, there was a perfect shower of them, all issuing as it seemed, from the same tract, and taking nearly the same direction towards the horizon, above which they were but a very few degrees, I cannot state with accuracy how many. It seemed to us something like the finale of a display of fireworks, if one could conceive them taking the same direction instead of diverging at all points.

"I remain, yours faithfully,

"JOHN J. IRWIN."

"Toronto, Canada, Oct. 13th.

No. 6.—"*Curious Meteoric Phænomenon.*—On Sunday evening, about six o'clock, a very brilliant meteoric ball darted forth from the zenith, and descended about half-way towards the horizon. It then burst as if it had been a rocket, displaying all the varied and beautiful shades of the rainbow. The sky at the time was clear and cloudless, the stars were shining prettily, but the dazzling glare of the meteor seemed for the moment to throw them into the shade."—*Globe*, Oct. 19, 1850.

No. 7.—Letters from Mr. G. A. Rowell.

"Alfred Street, Oxford, Dec. 2, 1850.

"Rev. Sir,—On Friday evening, November 23, about half-past seven o'clock, I was on the Woodstock road, a little north of the Observatory, when I saw a very beautiful meteor in the westward; it descended at a moderate pace, through about 15° of space, almost in a perpendicular direction, but a little towards the north. It appeared about double the diameter of Venus when at her brightest, was of a bright white or bluish colour, and left behind it a brilliant train which was distinctly visible throughout the whole space through which the meteor had passed, for full six seconds. The meteor did not seem to explode, but disappeared at a point *exactly* between the two stars α and γ Aquilæ.

"The same evening, about nine o'clock, a large meteor was seen descending also nearly perpendicular in the west. This was observed by a person in the Town Hall during the lecture, and must have been bright to attract the attention from a room so lighted.

"Again, about half-past eleven o'clock the same night, my wife was sitting by the fire with a lighted candle, when she was startled by a bright light, and, looking up, saw a very brilliant meteor pass the window from west to east, almost in a horizontal direction, but rather downwards. This meteor was seen by a very intelligent person in St. Clement's, who noticed its course with respect to certain stars, and can point out the direction. It was also noticed by several of the night-police men, and all describe it as having the appearance of a Roman candle of a bright bluish tint.

"My wife had, previously to this evening, told me of a very bright meteor about a quarter past ten o'clock on the night before, *i.e.* the 28th, not so large as the one on the 29th, but very much more so than usual.

"I take the liberty of troubling you with these particulars, as it seems extraordinary that so many large meteors should appear, when, at the same time, very few shooting stars were to be seen, as I was watching one or other part of the heavens on Friday evening, from seven to nine o'clock, and, excepting the one described, did not catch sight of *any other*, although the night was very clear.

"I am. Rev. Sir, your obedient Servant,

"G. A. Rowell."

"Alfred Street, Dec. 6, 1850.

"Rev. Sir,—Last night I saw another bright white-coloured meteor, about =Venus; it descended from somewhere about 6° or 8° east of Saturn, in a straight line a little towards the east of the perpendicular; its pace was moderate, and it left very little train. My view of it was rather imperfect, but I think, from the point at which it started to that of its disappearance, it could not be less than 25°. There were very few shooting stars last night; I only saw one, at about half-past nine o'clock; it was small, and passed with great velocity.

"There was *not* the slightest appearance of an aurora during both evenings, and I have only seen the aurora twice for some months past, and on both occasions I could not see one shooting star. I beg to suggest that it would be well if parties noting their appearance would notice whether there be an aurora during the time when there are many shooting stars, or during an aurora if there be many meteors.

"I am, Rev. Sir, your obedient Servant,

"G. A. Rowell."

No. 8.—Letters from the Rev. T. Rankin.

"Huggate Rectory, near Pocklington, Dec. 12, 1850.

"Dear Sir,—On the evening of Monday, the 9th, when coming home from a neighbouring village, with Ursa Major directly before me, shining with great splendour, a large luminous meteor made its appearance in the tail of Ursa, and moved nearly parallel with the body, then made a curved motion below the pointers, and disappeared about 10° above the horizon. The appearance was most brilliant; the tail was fan-shaped, about double the length or size of the body, which might be four times the size of either of the pointers. Before it disappeared the tail separated in a number of scintillæ. The evening was very clear, but a thick haze of about 10° edged the horizon. The day had also been calm and clear. At the time of the appearance the thermometer stood at 31°; barometer, 30·12; wet bulb of the hygrometer 2° below the dry (the motion was N.E.). Having expressed a wish, in your Report, for communications upon the occurrence of meteors, I take the pleasure of forwarding the present account;

"Remaining, dear Sir, yours very truly,

"*Professor Powell.*" "Thos. Rankin."

"Huggate Rectory, near Pocklington, Jan. 23, 1851.

"Dear Sir,—On looking over my meteorological memoranda for the last year, I find that on the evening of October 9th there appeared some common shooting or falling stars. There was at the same time some faint auroræ. Barometer 29·58; thermometer 42°. The moon in her 5th day.

"I do not know whether you observed the singular appearance of the moon in her 8th day on the evening of September 14th. It resembled a capital D with a flat bottom. The southern and eastern sides formed a right angle ∟. I thought at first that some optical illusion had caused the appearance, but having viewed her through some lenses, I found that the

appearance was the same as that by the naked eye. I repeated the examination at different times for more than an hour, with always the same appearance and shape. I could account for the perpendicular line, but not for the horizontal, unless it had been the shadow of a huge mountain. Leaving the matter to your superior judgment, I remain,

"Dear Sir, yours very truly,

"*Rev. B. Powell.*" "THOS RANKIN."

No. 9.—Extract communicated by Prof. Chevallier. "May 1, 1851.

"*Brilliant Meteor.*—An unusually bright meteor was seen at Durham, and in the neighbourhood, on the evening of Sunday, April 27, at $10^h\ 5^m$ P.M., mean Greenwich time. It was particularly noticed at Durham, at Bishopwearmouth, and at Esh, six miles west of Durham, and no doubt will have been seen over a large district of country. The following account is given by a gentleman of Durham, who observed the meteor from the cross road which leads from the London road, south of Durham, towards the Grammar School and South Street:—

"'It was a clear starlight night, when suddenly a blaze of soft yellow light overspread the country for some distance. The light seemed to fall gently on the ground and to run along it. It was so intense, and came on so suddenly, that I was startled by it. One or two seconds must have elapsed before I discovered the cause. This proved to be a beautiful meteor, which seemed to be about a quarter as large as the moon at the full. It was surrounded by a rich purple light, fading into blue; then a good deal of orange; and lastly, a light yellow, which was the colour of a considerable train which followed the meteor. It moved with considerable rapidity, and was visible for four or five seconds after I first discovered it. I could not tell whether it vanished into the air, or was hidden by some intervening object; but the impression on my mind was that it had fallen to the ground. It did not appear at any very great height; and, indeed, I listened for the sound of it falling, which I thought would most likely be heard very shortly after it disappeared.'

"Upon revisiting the place where this observation was made, and comparing the direction in which the meteor passed with the surrounding objects, it appears that the meteor, when first seen (which was some seconds after its light was first noticed), was at an altitude of about 70°, in the W.N.W. direction, and moved gradually towards the north, disappearing very nearly due north.

"The appearance of the meteor, as seen at Bishopwearmouth, was very similar.

"At Esh, the meteor was seen very favourably, the person who noticed it being on the side of a hill quite open towards the north. The light was so brilliant, that distant objects were seen as distinctly as in daylight. The meteor was estimated to be about half as large as the full moon; it appeared near the zenith in the north-west, and moved towards the north. When the meteor burst, sparks were distinctly observed to drip from it; but no noise was heard, either at the instant or within a few minutes afterwards.

"From the first description it appears, probably, that the meteor appeared somewhat nearer to the zenith at Esh than at Durham.

"Near Alden Grange, two miles west of Durham, the sparks falling from the meteor, when it burst, were distinctly observed, and appeared of a bright blue colour, compared to that of a lucifer match. One person there observed the meteor first in the S.E., moving gradually to the N.W.

"If this meteor should have been noticed in other parts of Great Britain, a comparison of different accounts may lead to a knowledge of its real course.

"TEMPLE CHEVALLIER."

No. 10.—Extract from a letter from Dr. Buist to Prof. Powell.

"*Meteors seen in India from June* 1850 *to May* 1851.
By Dr. Buist, F.R.S., Bombay.

"The following notices contain amongst them a list of meteors which have been seen in India, in so far as I have been able to observe or to hear from correspondents. The list does not in all likelihood contain a hundredth part of those that have been noticed by Europeans, or a thousandth part of those that have been visible in the sky; nor is there any reason to suppose that those which have been described have been by any means the most notable or conspicuous. In India we have probably not one man, at an average, for every thousand square miles, who thinks of making a note of, or of writing about such things; and all that can be done therefore is to accept of such notices as we receive,—drawing no conclusion from the number of meteors described as to the number or magnitude of those that have been visible. As the attention bestowed on such matters is every year on the increase amongst us, I am disposed to ascribe the scantiness of the list to a deficiency of meteors visible in our sky rather than to any defect in the number of exertions of the observers. I have myself not been able to see one-tenth of what I have been accustomed to notice, though my opportunities of observation have been as good as usual. There is a peculiarity in a large number of the meteors I have observed in India, which I do not recollect to have seen noticed. As they approach the termination of their course, they begin to shine out and disappear at intervals of about a quarter of a second, presenting the appearance closely allied to that of a disc or quoit thrown up in the air, and presenting alternately its edge and its face to the spectator. This occurs in general two or three, occasionally four or five times, before the extinction of the meteor, and does so equally whether it explodes or not.

"Of this list one aërolite has fallen to the ground, and been found, and forwarded to the Asiatic Society's Museum. A second has without doubt impinged upon the earth, but has not yet been discovered. It was seen in bright sunshine; the fragments thrown off alone appeared in a state of ignition; the central mass appeared black as it fell towards the earth, as if not heated to redness; and this most likely is the case almost always. But then at night when meteors are generally observed, it is the ignited portions that alone are visible. One meteor left a long train of hazy light behind it, which was visible for nearly twenty minutes, and was mistaken for a comet by those who had witnessed the train without observing the fireball itself. We have four remarkable instances on record in India of meteors vanishing gradually or leaving trains of light behind them after they had vanished: that seen in Palmacottah in 1838; it was the size of the full moon, and seemed to remain in one place for twenty minutes, when it grew gradually fainter and fainter, and then disappeared; that described by Capt. Shortrede as seen from Charka in 1842, which, with its train, was nearly five minutes visible; that seen from Calcutta on the 2nd December 1825, first visible as a ball of fire, then in the shape of a comet, in which form it remained for several minutes, when it vanished; and that described by Mr. Orlebar in the Bombay Observatory Report for 1846, seen on the 7th of December, and which left a luminous train behind it, visible for several seconds. The most notable instance of this sort is that of Jenny Lind's meteor seen from Boston on the 30th of September 1850, and which was visible for an hour. A very brilliant meteor was seen at Aden on the 1st of April. We have no particulars regarding it, further than this, that it was mistaken by the sentry at the Turkish Wall for an alarm rocket, and that he discharged his musket accordingly and gave the usual notice, when the whole garrison were sum-

moned to arms. This is perhaps the only meteor on record that caused 3000 men to be roused from their slumbers. Were officers in command of European troops in India to direct soldiers on duty to keep watch on the appearances of the sky, a vast mass of information on nocturnal phænomena might in a short time and with very little trouble be placed in our possession."

No. 12.—*Meteor of 2nd May* 1850, *observed at Bombay.*—A meteor seen from near Byculla Church on the 2nd of May seemed due east: first visible about 45°, it fell nearly 20° and then vanished without explosion. It was nearly pure white, increased in size as it descended, did not librate, and left no train behind it, and was at its brightest about the size of Jupiter.—G. B.

No. 13.—*Meteor of* 10*th June* 1850, *observed at Kishnaghur.*—"*To the Editor of the Morning Chronicle,*—Sir,—As the phænomenon I am about to record was a most extraordinary one, I hope you may receive further notices of it. Last night I was sitting in the open air with two other gentlemen at about twelve or thirteen minutes after ten o'clock, when a most beautiful brilliant meteor appeared, which we all saw. It issued from the heavens near a star of second magnitude about midway between Scorpio and a planet to the west; its direction was very nearly from south-west to north-east; it did not drop, but shot rapidly across the heavens, appearing to increase in size and brightness, and after proceeding a considerable distance (gaining rather than losing its splendid brilliancy) it burst and numerous luminous particles were discharged from it. About a quarter of a minute after it had so disappeared, and while we were expressing our wonder and admiration, a distant though loud rumbling sound commenced and reminded us of regimental file firing. At first we thought it might be thunder, though there were very few clouds, and they were only near the horizon. The sound continued for certainly half a minute, and we had time to receive the impression that it followed in the track of the meteor, when the sky was perfectly clear and bright. It was also seen by natives and described exactly.—J. C. Brown."

"Kishnaghur, June 11, 1850."

No. 14.—"*Meteor of* 1*st July* 1850, *observed at Bombay.*—On Monday evening, the 1st of July, about half-past seven o'clock, a beautiful meteor was seen to shoot across the sky from south-east to north-west for a distance of about 20°, when it exploded about 70° from the horizon, bursting with a bright flash into a number of pieces."—*Bombay Times,* July 3.

No. 15.—"Sir,—Did I, or did I not, see a comet yesterday (Nov. 6) evening in the south, about 15° above the horizon? It was about a degree, or perhaps two, in length, pointing towards the east. Whatever it was, it was very faint, so I might have been mistaken: this evening will decide it.—E."

"November 7."

"Sir,—I know not whether you have received any account of a shooting star which I saw last evening; if not, you are welcome to the following description of it. I was walking in company with a friend on the terrace of his bungalow, situated on Malabar-hill, about seven o'clock last evening, when our attention was directed towards that part of the sky from whence proceeded a sudden emission of intensely bright light, and we found it was caused by a large meteor which shot with inconceivable velocity across the heavens. Its course was from north-west to south-east, leaving in its track a luminous train. It was visible about three seconds, and then burst into innumerable stars of the most brilliant colours, very much resembling a large

and beautiful rocket. When first seen it was about 60° above the horizon, and passed within 10° to the north of Venus: it appeared a great distance off, and was doubtless traversing the remote regions of our atmosphere, as it exploded without any perceptible noise in the direction of Caranja, and at that time it could not have been more than 18° or so above the horizon. The most singular part of this phænomenon was, that after the meteor had burst into fragments, it left a stream of light behind about 10° or 12° in length, and for a time it strongly resembled the tail of a comet, with a nucleus of its own appended to it. I looked at it through an inverting telescope, and could plainly perceive a small bright spot like a star of the second magnitude, surrounded as it were by a luminous vapour or cloud. This nebulous appearance continued visible for full twenty minutes, when it gradually diminished in size, became more and more indistinct, and at last vanished altogether. The earth, it is well known, is at this moment travelling through the region of meteors in its annual orbit round the sun, and now is the period in fact when our globe incurs the liability of encountering streams of these shooting stars; and Sir John Herschel informs us in his 'Outlines of Astronomy,' that the meteors of the 12th to 14th of November, or at least the vast majority of them, describe apparently arcs of great circles passing through or near γ Leonis. No matter what the situation of that star with respect to the horizon, or to its east or west points, may be at the time of observation, the paths of the meteors all appear to diverge from it. I was unable last evening to prove the correctness of this theory, as I had no celestial map, and unfortunately I know not the exact position in the heavens of γ Leonis, nor the constellation in which it is placed, but this could be easily ascertained, and I shall therefore look again tonight at the quarter from whence this meteor came and see if the star alluded to is anywhere near, as I have no doubt Herschel is right. We should now be on the *qui vive* every evening for these interesting phænomena, as by a more extended series of observations a greater knowledge might be gained as to the real nature of these singular though beautiful periodical visitors. With hopes that you will excuse this hasty and imperfect sketch.—ASTER."—*Bombay Times*, Nov. 8.

"7th November, 1850."

"A Correspondent sends us the following:—'A meteor was observed from the Esplanade a few minutes before 7 P.M. on Wednesday evening, leaving an extraordinary train, traced one-third its flight midway from starting-point, and continuing in view all the time we remained there, say 15 minutes. Had our attention been drawn thereto accidentally, after the explosion of the meteor, we must have taken it for the comet expected in July last. Its course was from about 15° S.W. above Jupiter to 15° due south above the horizon; most brilliant and rapid in its descent, when it burst into numerous minor lights, much in the style of artificial meteors or sky-rockets, observed before from the same position.'"—*Telegraph and Courier*, Nov. 8, 1850.

No. 16.—"*November Meteors.*—The attention of several observers has lately been directed to the heavens, in hopes of seeing some indications of those annual 'showers of falling stars' which are noticed in November. Most of them appear to have been disappointed in their expectations,—lost their sleep and watched in vain. Sublunary affairs, unsought things, often fall in our way, while we pursue others to no purpose. By chance we found ourselves on the morning of the 14th toiling, not up, we are thankful to say, but down the 'many-winding way' of the Bhore Ghaut (the mountain pass betwixt

Bombay and Poonah), when we remarked numerous shooting stars, and, recollecting the period of the year, we determined to count them.

"In the course of one hour, from 5 to 6 A.M., thirty-eight of these aërolites passed across that part of the sky within the scope of our vision, and one bright comet-like meteor, almost at day-break, was alone worth the devotion of a whole night's watch had we been so philosophically inclined. But as we were walking, and only looking in one direction, it is probable that little more than an eighth of the celestial vault was under observation: it is not unreasonable to suppose that if the whole had been embraced at least 200 of these bodies might have been noticed. It is also probable that several escaped our attention, which was now and then required for other purposes than star-gazing when the precipices of Khandalla were near.

"There was nothing very remarkable in these aërolites, unless from their numbers. Their light, or, if you please, combustion, seemed to increase rapidly as they dived into the lower strata of the atmosphere, and finally disappeared with a faint explosion, or what *looked* like it, for it was not audible. Several of these must have been very near to the earth, as by their light they were distinctly seen to traverse the dark shade of the ravine below the summits of the mountains. The wind was easterly at the time, and appeared to influence the course of these astral travellers, which was generally from east to west.

"The most interesting object, however, was a large and brilliant meteor, which showed itself about a quarter before six, rushing from north-west to south-east, almost in an opposite direction to that followed by the smaller asteroids. A sudden blaze of light illumined the sides and very depths of the ravine, and, attracting our notice, we turned round and the cause was visible enough. A dazzling nucleus, about twice the apparent diameter of Jupiter when free from refraction, with a tail about 3° in length, and nearly as luminous as the head, was seen sinking behind the crest of the Ghauts on the Khandalla side; or rather I should say it inclined downwards, for it was evidently moving rapidly to the south-east, and, gradually fading into a pale reddish light, became invisible, not by a sudden coruscation or sign of explosion, for during the whole time that it was visible, about six seconds, the nucleus and its tail retained their original relative proportions, and became indistinct by loss of their luminousness, or from entering the beds of aqueous vapour in the lower part of our atmosphere.

"About an hour afterwards, on meeting a fellow-traveller who had also been descending the Bhore Ghaut at the same early hour, and inquiring if he had seen the meteor, he said 'no!' but he was surprised to find the *inside* of his palanquin suddenly lighted up by a bright but transient gleam.

"Even the brightness of Aurora's 'golden hair,' rising in the east, was thrown into the shade by this brilliant stranger darting across the sky. Whether there was a 'close current' or an 'isolated cloud of sulphur' resting on the Khandalla Ghaut we cannot pretend to say; neither are we bound to show from whence either originated, assuming their presence at the time. Certainly the dismal gloom before dawn which pervaded the deep chasm among the Ghauts, into which the road wends, reminded us of the entrance to that nameless region once visited by Æneas and a few others, famous for its sulphureous vapours."—*Bombay Times*, Nov. 24.

No. 17.—"We have been favoured with the subjoined account of a meteor observed at Shorapore, in the Nizam's dominions, on the morning of the 8th December:—'Notices of meteors always appear welcome to me, and I beg to add my mite to your collection this year. I was looking at γ Leonis just before daylight on the morning of the 8th instant; I had no watch to note

the exact time, when a bright yellowish glare suddenly illumined the telescope, and looking up I was in time to follow the course of a very fine meteor, which probably appeared somewhere in Leo, and had passed not far from the field of the telescope. There was a strong glare on the ground as the meteor passed on in the direction nearly of Arcturus, a little below which it burst into a number of brilliant balls and sparks. It was a little larger apparently than Venus at her greatest brilliancy, but the light was very vivid while it lasted. The most curious thing connected with it was, after the burst, the sparks or dust remained apparently in the same spot, or, falling into a spiral form, preserved a bright light not unlike that of the great nebula in Orion as seen through a telescope. I put the telescope on the spot instantly, and could see the sparks or dust slowly descending, some sparks being very bright indeed. This appearance lasted several seconds, and when I had taken my eye from the instrument, there was still a nebulous appearance in the sky, which however gradually faded. It is probable that this meteor burst not very far from the earth. The telescope was a 44-inch Dollond, with a power of 120. This is the most remarkable meteor I have seen this year, and though I have noted several others of remarkable appearance and brilliancy, yet there was nothing which required any particular mention to you. I think there have been quite as many small meteors or falling stars this year as I remember before, but your correspondents and yourself have taken ample notice of them, and the time is past when observations are necessary."—*Bombay Times*, December 18.

No. 18.—"We have heard of the fall of a remarkable aërolite, which took place at a village named Sulker, a short distance from Bissempore, on the 30th November (1850) at 3 o'clock in the afternoon. The fall was accompanied by an explosion, said to have resembled that of a cannon. The stone buried itself about 4 feet in the ground. On being extracted, it was found to be $3\frac{1}{2}$ feet round by $1\frac{1}{2}$. We hear that Captain Hannington has obtained possession of it, and that it will be forwarded to the Asiatic Society."—*Ibid.*

No. 19.—"We have received from a friend a letter, dated Camp Beerbhoom district, 8th January, 1851, giving the following description of a meteor, the more singular as seen in the day time:—

"'A meteor of surpassing brilliancy was seen this morning at twenty minutes past nine, in a N.N.W. direction; its elevation when first observed was about 25° above the horizon; its appearance was that of a brilliant electric spark-coloured ball of fire, with a narrow but bright train; its descent towards the earth was in an oblique direction, and when a few degrees from the horizon, it broke into a thousand brilliant and glittering particles of light, from amongst which a darker mass was seen to fall towards the earth, the glittering particles disappearing and reappearing as they fell; or to use a terrestrial simile, the numerous particles of light looked like a shower of broken glass, or a highly polished metallic surface glittering in a bright sunshine: the shower lasted a few seconds only. The sky was cloudless, and the sun shining brightly; thermometer in the shade 67° Fahr.'"—*Citizen*, January 11.

No. 20.—January 10th. A large meteor was seen at half-past one o'clock P.M. on the E. by N., as observed from the Esplanade. It first appeared about 45° from the horizon, was of a light red colour, and shot downwards and northwards; it vanished without explosion after traversing a path of about 15°. It increased in apparent size as it advanced, and left a long line of red sparks behind it, the whole extent of its path. These did not appear to change their position for some time after the disappearance of the meteor;

in about half a minute they dimmed and vanished. They were of the same bright red hue as the meteor itself. The meteor was about the size of the planet Jupiter at its brightest, and of a somewhat deeper tint than Mars.

No. 21.—January 16th. At a quarter past three o'clock A.M., Dr. Cole, Assistant-Garrison-Surgeon, on returning from visiting some of his patients, saw a very brilliant meteor, nearly double the size of the planet Venus at its brightest, shoot along from E. to S.W. It appeared to be about 18° above the horizon. It was followed by a long train of sparks, which disappeared almost simultaneously with the meteor. It vanished without explosion or change of appearance.

No. 22.—February 24th. A large meteor was seen by Mr. Tiller, merchant, Bombay, about ten P.M. It shot across the sky from S.W. to N.E., and vanished without explosion.

No. 23.—"A Correspondent mentions a striking and very beautiful phenomenon, seen from Mazagon about ten o'clock on Saturday evening, 19th April, when a display of meteors, following each other in succession, appeared from a point about 15° above the north-eastern horizon. In the space of little more than half an hour about twenty were observed; they darted across the sky in all directions: some of them shot upwards; by much the greater part moved towards the south or south-east. The largest of them were about the size of Venus at her brightest, and so down to mere specks of light. None of them were observed to explode, but the largest of them left long trains of light behind them."—*Bombay Times*, April 24th.

No. 24.—"The following is an extract from the letter of a Cawnpore correspondent:—'Your paper of the 24th ultimo came in this morning; I have intended writing you several days past, but I have been stirred up by your notice of the meteors at Mazagon, your correspondent states, the preceding Saturday [April 19]. We had here the precise similar beautiful phænomenon, time much the same, but your correspondent and myself differ by twenty-four hours, as I have noted them in my diary on Sunday evening as follows:—This evening from eight to ten P.M. constant meteors flying across, chiefly from N. towards S., often three or four at a time. The largest I did not see. I had my face towards N., facing a white building, when suddenly the whole was as bright as you see in a vivid flash of sheet lightning. Ere I could turn round it was out of sight, but leaving a vertical line of light, lasting perhaps ten seconds, from Sirius downward as far as I could see, a bungalow being close. This was the only vertical one, all the others shooting off at various degrees in a horizontal direction, but all from N.E. up to N.W., not towards, as all had a southerly direction. Your expressed wish to have information from those who may have seen the phænomenon, induced me to take up my pen.'"—*Bombay Times*, May 16.

No. 25.—"*Meteoric Showers of the 19th April.*—We extract the following notice from a Kolapore letter, of a magnificent shower of meteors witnessed there on the 19th; the same phænomenon was seen at the same hour from Bombay, and was described in our paper of the 24th; it is curious that no other notice of an appearance so striking should have been given us, though ten P.M. is, we allow, a bad hour for out-of-door observation in India:—'I do not see any mention made of the appearance elsewhere; but on looking out about half-past ten on the night of the 19th April, Sunday, the entire sky to the north was seen in a perfect blaze with meteors shooting from east to west. The phænomenon lasted about five minutes, when all was again still.'"—*Bombay Times*, May 6.

No. 26.—Letter from the Rev. T. Rankin.

"Huggate, near Pocklington, June 23rd, 1851.

"On the evening of February 16th, 1851, about half-past seven o'clock, a beautifully shooting star descended vertically from the right-hand of Bootes, about 15° above the horizon. It disappeared, after throwing off a violet-coloured veil, in a haze about 5° above the horizon: the appearance seemed about five miles distant.

"I remain, dear Sir, yours very truly,

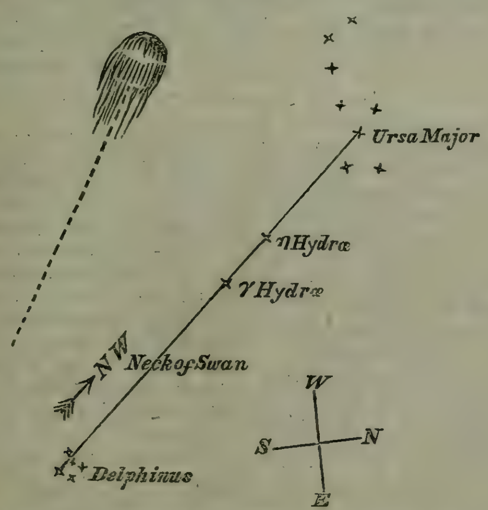
"*Rev. Professor Powell.*" "THO. RANKIN."

No. 27.—Considering the great interest attaching to the announcement made some years ago by M. Pettit, that one if not more meteors might be actual satellites performing regular revolutions round the earth, it seems surprising that so little should have been done by observers towards verifying this discovery or extending it, especially as the opportunities of doing so ought to be perpetually recurring. As possibly connected with this point, Sir J. Lubbock has kindly communicated the annexed list of meteors observed in past years, extracted from the Annual Registers. (See also Astron. Soc. Notices, x. 94.)

1758, 26th Nov. Edinburgh.
1759, 4th April. Bombay.
1762, 11th June. Sydenham.
1763, 15th January. Reading.
1763, 2nd September. Sweden.
1764, 31st January. St. Neots.
1764, 20th July. Philadelphia.
1765, 3rd May. Rome.
1765, 9th August. Greenwich.
1765, 8th October. London.
1765, 11th November. Frankfort.

No. 28.—From a Letter to Prof. Powell from E. J. Lowe, Esq.

Meteor seen at Kilkenny House, Bath, by Lieut. R. W. H. Hardy, R.N.
1851, June 20th, $11^h\ 30^m$.



No clouds visible. It moved horizontally. Apparent size = a large fire-balloon at a distance of 600 yards. Rate of motion about thirty miles an hour.

Its form was rounded on the advancing side. It left a clear thread of light as bright as α Hydræ along its whole course, which lasted three to four minutes with undiminished brilliancy, and then slowly faded away. It moved from Delphinus to Ursa Major. Lieut. Hardy thinks it was only 600 yards above our earth. "This is a mistake, for my brother saw it in London, but has not unpacked his account since his return."—E. J. L.

No. 29.—Letter from Dr. Buist, inclosing extracts from the 'Bombay Times.'

"Bombay, 27th May, 1851.

"Dear Sir,—I enclose you further extracts on the subject of the meteoric shower of the 20th April, seen all over India. You have now received accounts from the following places:—

	Lat.	Long.
Bombay	18° 58′	72° 38′
Poona	18° 30′	74° 02′
Kolapore	15° 37′	73° 38′
Cawnpore	26° 30′	80° 13′

The first and last of these places are above 1000 miles apart. I do not remember ever before to have seen notices of displays of this sort visible over so large an expanse of country. We must see and get soldiers on duty to make observations; a word from the War Office would effect all that is wanted at once. The Geographical Society here will always be delighted to play the part either of supervisors of observations, or receptacles for contributions, or to become the handmaid of science in any way, however humble.

"I ever am your obedient servant,

"*Professor Baden Powell, Oxford.*" "GEO. BUIST."

"We have been favoured with the following from a correspondent, who dates Cawnpore, 5th May, in reference to the meteoric showers seen from Mazagon and Kolapore on the 19th April. The phænomena agree so closely in all respects save date, that we should greatly wish our two previous informants to refer to their notes, and refresh their memories. We should like to make quite sure of the fact, as to whether meteoric showers, so remarkable as those referred to, were seen on two successive nights at nearly the same hour; or whether they were seen on the same night at Bombay, lat. 18° 56′, long. 72° 57′; at Kolapore and at Cawnpore, lat. 26° 30′, long. 80° 13′, the two extreme points being, as the crow flies, about 700 miles from each other. Our Cawnpore friend is far too exact and methodical, and attaches too much weight to such things to be in error. This, with the other notes of meteors and hail-storms that have been forwarded to us, as well as the valuable paper on the meteorology of Futtegurh, just received, will be forwarded to the British Association. An account of them will, we doubt not, be in due time found in the reports of the July number of the 'Athenæum,' as well as in the extended Reports of the Association:—'Your paper of the 24th ultimo came in this morning. I have intended writing you several days past, but I have been stirred up by your notice of the meteors at Mazagon, your correspondent states, the preceding Saturday. We had here the precise similar beautiful phænomenon, time much the same, but your correspondent and myself differ by twenty-four hours, as I have noted them in my diary on Sunday evening, as follows:—This evening from eight to ten P.M. constant meteors flying across, chiefly from N. towards S., often three or four at a time. The largest I did not see. I had my face towards N., facing a white building, when suddenly the whole was as bright as you see in a vivid flash of sheet lightning. Ere I could turn round it was out of

sight, but leaving a vertical line of light, lasting perhaps ten seconds, from Sirius downward as far as I could see, a bungalow being close by. This was the only vertical one, all the others shooting off at various degrees in a horizontal direction, but all from N.E. up to N.W., not towards, as all had a southerly direction. Your expressed wish to have information from those who may have seen the phænomenon induced me to take up my pen. Since my list of hail-storms, I have only had to record one under my own observation, and which occurred about three P.M. at a place called Oomree, seven miles west of Rewah, on the 7th February last, the hailstones fully as big as pigeons' eggs. It did not last long, but was very violent, and tore my tent sadly. This village, Oomree, must have been about the centre, as it did not extend to Rewah east, and only about four miles to the westward, as my camels were about that distance, and had only rain.'"

"We feel greatly indebted to a Poona correspondent for the following account of the meteors of the 20th ultimo, of which we have already published several notices; we trust that we shall be able to secure a few more; those that have hitherto reached us are all perfectly consonant with each other:—'In your issue of the 15th you wish for further information regarding the shower and meteors seen last month. I can speak positively that it was seen here on Sunday the 20th about ten o'clock. I was sitting outside my house with a friend, and we observed two or three in a minute. One was of surpassing brilliancy; it left a tail (if I may so express myself) which lasted at least a minute. With one exception in the north, which fell, they all went from east to south-west.'"

"We find that the shower of meteors, mentioned in our paper of the 24th as having been seen from Mazagon on the evening of the 19th, was in reality observed on the 20th; we have no doubt that a similar error will be found to have occurred in reference to the date on which they were visible at Kolapore, so as to identify the display with that observed from Cawnpore on Easter Sunday. At any rate, we have the matter now established in reference to the exhibition as witnessed from two extreme stations, and this is the most striking point of the whole."

No. 30.—Extract from a letter from Mr. Frost.

"Ipswich, July 4th, 1851; and at Chatham Place, Hackney.

"Rev. Sir,—I have great pleasure in sending you a communication I have received from Lieut. Gawler of the 73rd Regiment in British Caffraria; the extract from the letter is as follows:—'On Tuesday morning, March 11th, 1851, we commenced our march in two divisions at one A.M., one under Colonel Mackinreon, and the other under Colonel Eyre; we reached the mountains about day-break, in lat. 32° 40′ S., and long. 27° 30′ E., when we saw a most curious meteor, which passed us within 30 feet, with a loud hissing noise, like a spent ball, going as fast as a bird would fly; it appeared like a ball of fire about half the size of an egg, with a tail of fire about a foot long. It was seen by the other division six miles to the east of us.'

"Another remarkable meteor was seen on Sunday night, the 22nd ultimo, at 11 o'clock, at the east part of London, about 30° of altitude; this appeared like a brilliant ball of fire, leaving a stream of light about 60° long.

"I am, Rev. Sir, your obedient servant,

"*To the Rev. Baden Powell.*" "WM. FROST."

No. 31.—Extract from a letter from Mr. Cameron to Prof. Stevelly.

"Belfast, 30th June, 1851.

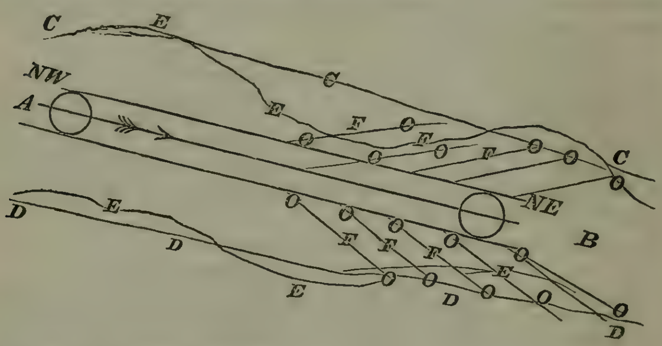
"My dear Sir,—On the evening of June 22nd, when in my parlour, I ob-

served a large ball of a whitish red appearing north-west from where I was, and I think about one mile from me, and about half a mile from the surface of the earth; it seemed at first enveloped in a cloud or haze, but upon emerging out it showed about the size of the full moon, travelling *slowly* from west, and taking an easterly direction; after having travelled about 100 yards, it began to throw out small ball-like comets in every direction, and the balls had a greater velocity than the main body, and preceded it for a short distance; and before each ball exploded, it became scarlet-red, and threw out small shocks of matter; and after the ball had travelled 400 or 500 yards, it then appeared to be totally exhausted, and as it were dissolved, without showing any remnant of matter. After this, the whole length that the large ball travelled had the appearance as if the space were filled with a reddish-white matter, and remained so for seven minutes, and then became to get disordered and irregular, and in three minutes got spread, or flattened, and ultimately dispersed, apparently by contrary currents of air. I might mention, that from my residence adjoining New Court House, the first appearance I observed of the ball was over Mr. Reid's farm, west of Old Park, and the direction taken was that of Mr. Harris's works, and then towards the Upper Dam; but certainly it did not reach so far.

"I am, dear Sir, yours very truly,

"J. Cameron."

The annexed diagram represents the appearance.



A B, course of centre of meteor.

F F F F, &c., small balls and lines of light projected in advance of its course, and oblique to it.

C C C, D D D, outer boundary of reddish space which remained long after disappearance of meteor and small balls.

E E E, E E E, waving appearance this red space assumed when beginning to break up and dissipate.

Eleventh Report of a Committee, consisting of H. E. Strickland, *Esq.*, Prof. Daubeny, Prof. Henslow, *and* Prof. Lindley, *appointed to continue their Experiments on the Growth and Vitality of Seeds.*

In the spring of the present year the allotted portions of each kind of seed gathered in 1843, being the third sowing of such kinds, were subjected to experiment, under circumstances similar to those resorted to on previous occasions*.

So few additions have lately been made to the Depôt at Oxford, that it becomes a duty on our part, to request that persons interested in these experiments, will lend their aid by contributing seeds of known date, and where possible, in quantities sufficient for distribution, especially those of genera not included in the list given in the Report for 1848.

The annexed Table contains the names, &c. of the kinds sown :—

Name and Date when gathered.	No. sown.	No. of Seeds of each Species which vegetated at			Time of vegetating in days at			Remarks.
		Oxford.	Cambridge.	Chiswick.	Oxford.	Cambridge.	Chiswick.	
1843.								
1. Asphodelus luteus	50	......	......	1	......	......	14	Those sown at Chiswick were placed in a moderately warm pit. At Oxford and at Hitcham they were not so treated.
2. Arctium Lappa	100	......	......	3	......	......	16	
3. Angelica Archangelica	100							
4. Allium fragrans	100	......	......	4	......	......	13	
5 Borkhausia rubra	100	......	......	2	......	......	10	
6. Bartonia aurea	200	......	......	1	......	......	8	
7. Campanula Meadia	100							
8. Dianthus barbatus	100	......	......	2	......	......	14	
9. Euphorbia Lathyris	50							
10. Gypsophila elegans	200	......	......	6	......	......	7	
11. Hesperis matronalis	100	......	......	2	......	......	13	
12. Hypericum hirsutum	150							
13. Kaulfussia amelloides	100	......	......	1	......	......	8	
14. Loasa lateritia	150							
15. Œnanthe Crocata	100	......	......	2	......	......	10	
16. Plantago media	150							
17. Polemonium cœruleum	100	......	......	2	......	......	8	
18. Rumex obtusifolia	150	38	......	14	16	......	10	
19. Silene inflata	50	2						
20. Smyrnium Olusatrum	100	......	......	2	......	......	20	
21. Tigridia Pavonia	100							
22. Ageratum mexicanum	200	......	......	3	......	......	16	
23. Aster tenella	200							
24. Bidens diversifolia	150	......	......	2	......	......	10	
25. Biscutella erigerifolia	100							
26. Callistemma hortensis	200							
27. Centaurea depressa	100	......	......	3	......	......	14	
28. Cladanthus arabicus	200							
29. Cleome spinosa	100							
30. Convolvulus major	50	5	......	4	......	......	20	
31. Echium grandiflorum	100							
32. Eucharidium grandiflorum	200							
33. Helenium Douglasii	200							
34. Hebenstretia tenuifolia	100							
35. Heliophila araboides	200							
36. Koniga maritima	200							
37. Leptosiphon androsaceus	200							
38. Lunaria biennis	100							
39. Matthiola annua	200							
40. Melilotus cœruleus	100	10	4	5	16	15	16	
41. Phytolacca decandra	25							
42. Schizanthus pinnatus	200	1						
43. Talinum ciliatum	200	......	......	5	......	......	13	
44. Viola lutea vars.	150	......	......	1	......	......	14	

Remarks on the Climate of Southampton, founded on Barometrical, Thermometrical and Hygrometrical Tables, deduced from observations taken three times daily during the years 1848, 1849 *and* 1850. *By* JOHN DREW, *F.R.A.S., Ph.D. University of Bâle.*

SHORTLY after the Meeting of the British Association in Southampton, I determined upon commencing a series of meteorological observations in that town: its position in the centre of the southern line of coast appeared to me an important one, and in this view I was confirmed by those whose authority stands high on meteorological science. I entered therefore on an unbroken series, with the hope of supplying data for the determination of the climate of the place, towards which object no systematic efforts had as yet been directed.

With this view I consulted Mr. Birt, as to the instruments best adapted to the purpose, and he kindly undertook to superintend the construction of a Barometer by Mr. Newman, from whom, at his recommendation, I procured the greater part of the instruments employed in the observations, the results from which I am about to lay before the Section—for the most part in a tabular form. I have spared no pains in arriving, as near as possible, at absolute mean values in the instrumental readings; and for the purpose of satisfying those who may hereafter consult the Tables, I shall accompany them with a few remarks on the plans adopted and the instruments employed.

The observations have been taken three times daily, viz. at 9 A.M., 3 P.M., and 9 P.M., local mean time, for a period of three years, extending from Feb. 1, 1848 to January 31, 1851. The barometer, with its attached thermometer and the wet and dry-bulb thermometers, have been read at these hours; the force and direction of the wind and the amount of cloud recorded: in addition to these, at 9 A.M. daily, the readings of the maximum and minimum thermometers, and the amount of rain during the previous 24 hours, have been registered. The system pursued has been as nearly as possible in accordance with that followed in the Greenwich observations.

The Latitude of my Observatory is 50° 54′ 34″ North.
The Longitude in Time $0^h\ 5^m\ 37{\cdot}7^s$ West.

The height of the barometer cistern above the mean level of the sea is 60 feet; and of the rain-gauge above the surface of the ground 9 feet 6 inches.

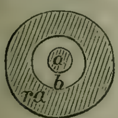
TABLE I. shows the mean height of the barometer for every month, with the highest and lowest readings, and their difference, or monthly range. These have been corrected for capacity and capillary action, and have been reduced to the temperature of 32° Fahrenheit.

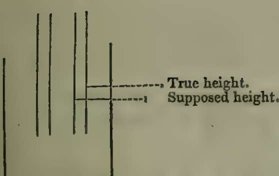
To determine the zero correction, Mr. Birt undertook to compare the instrument, before it came into my hands, directly with the Royal Society's Standard, and indirectly with a mountain barometer of Col. Sabine's, whose index correction had been previously ascertained: the result of the whole series of comparisons was the necessity of applying $+0{\cdot}036$ in. to the readings of my barometer to bring them up to those of the standard: this has been applied in every case; although when on a late occasion I carefully compared it with others whose correction was thought to have been known I found it somewhat too great, yet the differences were not so consistent as to induce me to alter the index-error as originally determined.

The barometrical readings have not been corrected for daily range, as I have reason to believe that the daily periods of atmospheric pressure do not

coincide with those at Greenwich. On frequent occasions I have applied separately to the monthly means of the 9 A.M., 3 P.M. and 9 P.M. observations, the corrections given by Mr. Glaisher in the Phil. Trans. part 1, 1848, and the results were in no case consistent: nor is this surprising, when we regard the situation of Southampton at the head of an estuary which is divided into two arms by the Isle of Wight. Most probably the local variations of atmospheric pressure are peculiar, but what these may be can only be determined by a far more extensive series of observations than I have had the leisure to undertake: one on the plan of photographic registration would admirably answer the purpose.

Mr. Glaisher on one occasion expressed himself to me unfavourably with regard to barometers to which it was necessary to apply the capacity correction. His reason was, that as the mercury descends in the tube and the cistern becomes fuller, a portion of the hollow cylinder of glass composing the tube is enclosed, and the mercury rises higher than the capacity correction would indicate, by a quantity dependent on the volume of the section of the tube which it had enclosed. After having carefully considered the subject, I entered upon an investigation which should result in leading me to reject the observations I had taken, or to confirm my confidence in them.





Let $a =$ the area of the hollow part of the tube.

$ra =$ the area of the surface of the cistern.

$b =$ the area of the annulus or section of the glass tube.

$c =$ the ascent or descent of the mercury from the neutral point.

$x =$ the correction required, + in the former case, — in the latter.

Then $ac = (ra - b)\,x$,

or $x = \dfrac{ac}{ra-b}$.

Substituting the values of these quantities measured from my barometer, the internal diameter of the tube being 0·283 in., the external 0·41 in., and the proportion between the area of the section of the tube and that of the cistern as 1 to 42, we have $a = 0{\cdot}0629$, $r = 42$, $b = {\cdot}0691$; let $c = 1$ inch,

then $$x = \frac{{\cdot}0629}{2{\cdot}535 - {\cdot}069} = {\cdot}0248;$$

but the correction for capacity, as applied in the usual way,

$$= \frac{ac}{ra} = \frac{1}{42} = {\cdot}0238;$$

it follows therefore that when the mercury has ascended or descended from the neutral point one inch, the difference caused by the enclosure of the tube will be exactly ·001; a quantity less than that read by the vernier—probably less than the error of observation—and therefore one which may fairly be neglected in practice. If therefore the exact proportion between the areas of the tube and cistern be carefully ascertained by the maker, we are able to arrive at sufficient correctness with a barometer to whose readings it is necessary to apply the capacity correction; the trouble of reading off is less. I have tabulated the capacity correction and the index error; so that by taking

the algebraic sum of one quantity and the correction for temperature, I get the true reading directly, and with little labour; while there is a great advantage in the cistern being of iron, and in getting rid of the leathern bag which accompanies some barometers of a certain construction.

On comparing the pressure at Southampton with that at Greenwich monthly, I find a difference varying between 0·110 in. and 0·145; the height of Greenwich observatory above my station, measured from the level of the sea, is 100 feet.

	Greenwich.	Southampton.	Difference.
11 months of 1848	29·711	29·839	0·128
12 months of 1849	29·801	29·943	0·142
12 months of 1850	29·812	29·949	0·137

The consistent results, arising from reducing the readings to the sea-level and deducting such portion of the pressure as is due to the aqueous vapour in the atmosphere, tend to give considerable confidence in the barometrical observations.

Mean pressure of dry air reduced to the level of the sea.

	Greenwich.	Southampton.	Difference.
1849	29·692	29·677	·015
1850	29·697	29·686	·014

Table II. Determination of the mean temperature.—The dry and wet-bulb thermometers were compared by Mr. Glaisher and myself with a standard by immersion in water of a high temperature, which was allowed to cool gradually, simultaneous readings being taken from time to time: the result was that the dry-bulb was found to read too high by —·4 in., and the wet-bulb by —·2: to the means of the monthly observations these corrections have been applied; and by an extended series of simultaneous readings, the indications of the maximum and minimum thermometers have been corrected and reduced to the same standard.

Mr. Glaisher's corrections for daily range have been applied to the 9 A.M., 3 P.M. and 9 P.M. observations, and the mean monthly temperature thus deduced; the quantities given by him have also been subtracted from the arithmetical means of the maxima and minima, to obtain an independent mean temperature: although these two results, as may be seen by inspection, are not absolutely identical in every case, they are sufficiently near to show that the variations in the rise and fall of the temperature occur at Southampton at nearly, if not quite, the same local time as at Greenwich. Mr. Glaisher considers that these corrections might not apply to localities on the coast, and that the agreement is nearer than might have been expected. Taking the entire series, the following is the result:—

	1848.	1849.	1850.	Whole series.
M. T. from the daily obs.	51·4	50·2	49·4	50·3
M. T. from max. and min.	52·1	50·1	49·1	50·4
Difference	0·7	0·1	0·3	0·1

This table also shows the mean of the maxima and minima; the highest and lowest readings during the month, with the date of their occurrence; and the differences between these, or monthly range of temperature.

Table III. gives the monthly means of the readings of the dry and wet-bulb thermometers reduced to the mean temperature by the application of

Mr. Glaisher's corrections; the dew-point deduced by the factors given in the Greenwich observations; the degree of humidity, and the mean amount of cloud, considering a cloudy sky to be represented by 10, and a cloudless sky by 0.

From this table I find, as my experience had told me, that the atmosphere of Southampton is moist compared with places farther inland; nor will this be a matter of surprise when we regard its situation between two rivers (one of which is a mile in breadth for a considerable distance above the town), and on an arm of the sea, from which the prevalent winds are constantly wafting the over-laden clouds.

The degree of humidity as compared with Greenwich, situated inland and on a considerable elevation, approaches, as might be expected, nearer the point of saturation.

	1848 (11 mo.).	1849.	1850.
Greenwich	·820	·802	·805
Southampton	·878	·844	·861

Table IV. shows the prevalent winds for each month during the three years; it has been formed by inserting under each head the number of times the direction has been recorded at 9 A.M. and 3 P.M.

In the year 1848, the south, south-west, and westerly winds were largely in the ascendant, and the consequence was an exceedingly wet season, as these winds were usually accompanied with rain; they are, for the most part, warmer than those from the northward and eastward, and hence we find the mean temperature of that year higher by 2 degrees than 1849, and by 3 than 1850.

In 1849, the northerly and north-easterly winds were frequent; the proportion between those winds from the quarters north to east inclusive, and those between south and west, being as 254 to 321. The difference in the fall of rain during this year and the preceding, amounted to upwards of 10 inches: the loss of the January observations prevents my stating the exact amount.

In 1850, the south-west winds predominated over the north-east in the proportion of 372 to 252; the amount of rain collected was as nearly as possible the same as in 1849. The mean temperature was low, especially in the months of January, March and October, when the wind set frequently from the north and north-east, as the tables will show. During the month of March especially, the low degree of humidity shows the dry nature of the air on the prevalence of the northerly wind. In the month of March, generally the north and north-east winds prevail, while winds from the south and south-west are about equally distributed throughout the other months of the year.

Table V. requires but little explanation or remark. It exhibits the monthly mean of the readings of two thermometers, one near the surface of the soil protected from the sun's rays, the other sunk 1 foot below: they have been read off simultaneously at 3 P.M. daily during the year 1850.

Table VI. is a contribution towards the comparison of the climate of different localities, and exhibits certain conditions of the atmosphere, as instanced at Southampton and three other places; viz. Falmouth, which is near the most southern and western point of England; Stone, between Aylesbury and Oxford, a central situation; and York, a northern position, and also inland. By the courtesy of the gentlemen who have kept constant meteorological registers at those places, I have been supplied with the particulars on which the table is based: these are,—

1. The number of days on which the temperature fell below the freezing-point.

2. The number of days on which rain fell in greater quantities than half an inch in 24 hours.

3. The amount of rain in inches during each month of the three years.

4. The number of days on which rain fell.

5. The mean temperature of each month for each of the four places mentioned.

Confessedly imperfect as this table is, we may nevertheless deduce from it some interesting facts. It is imperfect from the construction of the rain-gauges employed, which would give more satisfactory results did they record the duration of showers of rain as they fell on the principle of Osler's rain-gauge. They are imperfect indicators, moreover, of the mean amount of rain for their localities, from the varying height at which they are placed above the ground. I apprehend that to obtain the due amount of rain we should plant several gauges in different parts of a town, and the mean of the quantity received would give a much fairer estimate. Till, however, the number of those who take an interest in the subject of meteorology is greatly increased, we must be satisfied with such imperfect means as we possess for acquiring a knowledge of the atmospheric variations and the laws which regulate them, of even so small a portion of the world as our own country.

The following are a few particulars deduced from the table under consideration :—

1. During the course of the year, the number of days on which the freezing-point is reached at Falmouth is about $\frac{1}{4}$ of that at Southampton, at Stone $1\frac{1}{2}$, at York $1\frac{2}{5}$.

2. With regard to the number of falls of rain beyond $\frac{1}{2}$ an inch in 24 hours, Southampton and Falmouth are about equal; at Stone and York the number of such days is $\frac{1}{3}$ of those at the former places.

3. The entire quantity of rain at Falmouth during the three years is somewhat more than $\frac{1}{10}$th beyond that at Southampton; at Stone and York somewhat more than half the quantity at Falmouth; York having received 77·6 in., and Stone 68·3.

4. The number of days on which rain is stated to have fallen is *less* at Southampton than at any other place; being 474 to 577 at Falmouth, 502 at Stone, and 519 at York. This result is consistent with that just mentioned and with the table that follows, and leads us to the conclusion that the rain falls in larger quantities at Southampton than at any of those places with which I am comparing it.

The days and amounts of falls of rain exceeding one inch in 24 hours during the time through which these observations have extended, are as follow :—

Southampton.			Falmouth.		Stone.		York.	
1848.	June 10.	1·055	Sept. 25.	1·268	....		June 18.	1·63
	June 17.	1·025	Dec. 27.	1·500	....		Sept. 25.	1·99
	Oct. 24.	1·215						
1849.	Oct. 4.	2·105	Sept. 22.	1·925	May 28.	1·3		
	Dec. 8.	1·810	Sept. 26.	1·964				
1850.	June 27.	1·960	May 6.	1·750				
	July 18.	1·588	July 3.	1·100				
	Sept. 28.	1·130	Aug. 7.	1·024				
	Nov. 25.	1·636	Sept. 24.	1·900				
			Dec. 15.	1·306				
1851.	Jan. 21.	1·300	Jan. 21.	1·222				
	Sums	14·824		14·959		1·3		3·62

It would appear, then, in conclusion, that the climate of Southampton is mild, differing but little from that of the most southern town in England; that the air is more generally laden with moisture than that of inland towns, arising from its proximity to the sea and freshwater, and from the prevalence of winds from the points between south and west and those inclusive, which are laden with aqueous vapour from the sea: that this moisture falls in copious showers on a fewer number of days than the less quantity in the inland towns with which it has been compared; occasionally in large quantities at a time, as on June 27*, 1850, when nearly two inches of rain, accompanied with thunder and lightning, fell in 12 hours: that severe cold is less prevalent than at places inland, but the quantity of rain is greater; while the average amount of cloud appears, from comparison with about forty other places, to be a mean between the more and less cloudy skies. Though the air may be less bracing than places higher and more inland, we have the advantage comparatively in mild winters, and the absence of that severity which is so trying to the invalid.

I avail myself of a high medical authority to subjoin the following enumeration of the prevalent diseases, and of those which are unusual in the neighbourhood; which, being written entirely independently of my observations, will, I apprehend, be yet found to harmonize with the opinions which I have founded on the meteorological observations.

"Inflammatory diseases of an active kind are not at all common, nor do they require or bear active depletion when they occur. The town is quite free from ague: the mud lands do not produce it, as the water upon them is never stagnant. Intermittent neuralgias are not met with. Fever is not common. Twenty years ago it was very rare, but since the town has increased greatly in numbers it is more prevalent, though not of a malignant type. There is a considerable amount of complaint from uneasiness, discomfort, indisposition and local pains produced by indigestion of an atonic kind, or the result of want of general power. The system is not so vigorous as in a more bracing climate, and therefore not so able to digest the same quantity of food; and unless much greater attention is paid to quantity especially, and also quality as well as to habits, headache, distension, constipation and general debility are not uncommon. Young and vigorous persons who come here from a colder and drier air, usually complain at first of sleepiness, and an inability to perform the same amount of muscular or mental exertion. On the other hand, rather delicate and susceptible people (especially women), who are never well in colder parts of England, enjoy much more bodily comfort here. For the same reason it suits children and elderly people, especially if they have been subject to inflammatory diseases of the air-passages in colder or drier places. Gouty and rheumatic diseases are not common here, as might be expected, from the inability to digest a large quantity of food; in short, there is a greater amount of indisposition from indigestion, and a less than an average amount of active secondary diseases, such as fever and violent inflammation."—Dr. J. Bullar.

Looking at what private observers like myself have been able to accomplish in the science of meteorology, we must arrive at the conclusion that comparatively slow progress will be made until our number is greatly increased, and till we embrace in our observation a more extensive range. In addition to the pressure, temperature, and hygrometric state of the air, it would be highly advantageous, could we, for all localities, ascertain in addition the rapidity of evaporation; the range and intensity of solar radiation; and the state of electric tension,—all which in their varied combinations go to make up that general result which we call *climate*, and which unitedly produce effects upon the natural world and the human frame, according to the preponderance in the atmosphere of one or the other element.

* This was the heaviest fall of rain recorded.

Table I.

Atmospheric Pressure.

	Mean height of the Barometer.	Highest reading during the month.	Date of the occurrence.	Lowest reading during the month.	Date of the occurrence.	Monthly range.
1848.						
February	29·645	30·459	18	28·396	26	2·063
March	29·621	30·287	8	28·753	12	1·534
April	29·710	30·119	30	29·270	19	0·849
May	30·038	30·295	11	29·299	17	0·996
June	29·787	30·146	20	29·231	3	0·915
July	29·971	30·448	12	29·365	20	1·083
August	29·861	30·098	31	29·411	1	0·687
September	29·958	30·407	16	29·285	24	1·122
October	29·765	30·252	13	29·361	27	0·891
November	29·945	30·492	13	29·120	23	1·372
December	29·929	30·364	22	29·139	5	1·225
Mean	29·839					
1849.						
January	29·939	30·564	23	29·431	28	1·133
February	30·256	30·855	11	29·216	23	1·639
March	30·055	30·683	6	29·191	28	1·492
April	29·636	30·296	30	29·197	19	1·099
May	29·905	30·226	11	29·258	17	·968
June	29·988	30·215	3	29·633	10	·582
July	29·934	30·344	12	29·479	24	·865
August	29·997	30·366	20	29·629	13	·737
September	29·886	30·319	19	29·198	30	1·121
October	29·882	30·684	29	29·082	4	1·602
November	29·871	30·387	8	29·115	4	1·272
December	29·975	30·580	27	29·257	5	1·323
Mean	29·943					
1850.						
January	29·986	30·536	27	29·387	15	1·149
February	30·010	30·408	22	29·086	5	1·322
March	30·191	30·632	6	29·549	23	1·083
April	29·755	30·337	9	29·094	16	1·243
May	29·806	30·259	2	29·379	8	·880
June	30·052	30·374	19	29·460	14	·914
July	29·977	30·198	30	29·614	25	·584
August	29·928	30·343	31	29·608	21	·735
September	30·039	30·454	8	29·402	30	1·052
October	29·774	30·414	13	29·181	23	1·233
November	29·856	30·367	9	28·720	20	1·647
December	30·017	30·624	23	29·136	18	1·488
Mean	29·949					
1851.						
January	29·738	30·297	23	29·046	15	1·251

Table II.

Temperature.

	Mean temperature from three observations daily.	Mean of the maxima.	Mean of the minima.	Mean temperature from maxima and minima.	Adopted mean temp.	Highest reading during the month.	Date of the occurrence.	Lowest reading during the month.	Date of the occurrence.	Monthly range.
1848.										
February	43·3	49·5	38·5	43·3	43·3	54·1	27	25·6	18	28·5
March	43·6	54·2	39·1	46·6	45·1	67·1	31	30·1	15	37
April	47·7	59·9	41·6	49·1	48·4	74·3	5	29·1	10	45·2
May	58·7	72·9	46·7	58·1	58·4	80·6	24	38·1	1	42·5
June	56·7	70·2	52·2	59·4	58	82·6	23	44·6	2	38·0
July	61·7	74·1	54·2	62·2	62	86·1	18	42·1	1	44
August	58·5	69·6	53	59·6	59	76·1	13	44·1	10	32
September	56·9	68	49·1	57·2	57	75·3	3	39·1	12	36·2
October	51·9	58·9	46·5	51·7	51·8	71·1	8	35·6	18	35·5
November	42·8	49·7	36·4	42·6	42·7	58·1	1	28·1	16	30
December	44·1	48	40	44	44	59·5	12	29·1	21	30
Means	51·4	......	......	52·1	51·8					
1849.										
January	40·1	44·9	35·2	39·8	40	52·6	15	27·6	12	25
February	43·6	50	36·6	42·7	43·1	58	23	27·6	13	30·2
March	43·2	50·6	37·6	43·1	43·1	62·2	13	27·1	11	35·1
April	44·4	53·6	38·6	44·6	44·5	65·2	30	28·4	21	36·8
May	57·1	72·8	48·2	58·8	58	84·3	24	36·1	5	48·2
June	59·5	73·4	51·5	60·7	60·1	87·6	24	42·5	11	45·1
July	60·8	70·6	53·1	59·9	60·3	83	16	42·6	1	40·4
August	61	69·9	54·5	60·5	60·7	77·6	8	41·6	17	36
September	56·3	65·9	50·7	57	56·6	76·6	5	37·6	19	39
October	51·6	57·7	46·4	51	51·3	63·8	28	32·6	10	31·2
November	45·5	50·3	39·9	44·8	45·1	58·6	10	19·3	28	39·3
December	39·9	43·5	34	38·7	39·3	54·6	15	10·6	29	44
Means	50·2	......	......	50·1	50·2					
1850.										
January	34·9	38·7	29·2	33·8	34·4	51·9	30	9·6	14	42·3
February	44·6	49·3	39	43·8	44·2	54·8	10	27·6	13	27·2
March	40·4	46·7	32·6	38·7	39·6	59·6	8	21·6	26	38
April	48·4	56·5	43·6	48·6	48·5	64·6	2	35·8	23	28·8
May	51·6	60·3	48·4	52·5	52	74·9	30	29·9	3	43
June	59·5	71·1	51	59·2	59·4	81·6	25	39·4	15	42·2
July	61·6	71·6	56·4	62·1	61·9	82·6	16	46·6	8	36
August	59·5	70	53·8	60·2	59·8	77·8	1	41·1	22	36·7
September	56·3	65·2	48·4	55·5	55·9	72·8	3	37·6	9	35·2
October	46·6	54·1	40·2	46·2	46·4	62·6	19	31·6	24	31
November	47·1	52·8	41·3	46·7	46·9	60	1	27·8	15	32·2
December	42·8	47·1	36·8	42	42·4	53·1	6	26·4	21	26·5
Means	49·4	......	......	49·1	49·3					
1851.										
January	44·5	49	40	44·5	44·5	53·6	2	30·6	23	23

Table III.

Hygrometrical state of the Atmosphere.

	Dry bulb.	Wet bulb.	Wet below dry.	Dew-point.	Degree of humidity.	Amount of cloud.
1848.						
February	43·3	42	1·3	40·2	·906	6·4
March	43·6	42·5	1·1	41	·880	7·3
April	47·7	45·9	1·8	43·7	·877	7
May	58·7	54·5	4·2	50·7	·788	2·5
June	56·7	54·8	1·9	53·1	·896	7·3
July	61·7	59	2·7	56·9	·858	6
August	58·5	56·7	1·8	55·1	·903	7
September	56·9	55·1	1·8	53·5	·901	7
October	51·9	49·8	2·1	47·7	·868	6
November	42·8	41·4	1·4	39·5	·873	6·5
December	44·1	42·8	1·3	41·1	·909	7
Means	51·4	......	......	47·5	·878	6·4
1849.						
January	40·1	39·1	1	37·7	·926	8
February	43·6	42·1	1·5	40·2	·892	6·8
March	43·2	41·1	2·1	38·2	·853	7
April	44·4	42·2	2·2	39·4	·848	6·3
May	57·1	53·3	3·8	49·9	·806	6·4
June	59·5	54	5·5	49·6	·731	5·1
July	60·8	56·3	4·5	52·7	·775	5·3
August	61	57·5	3·5	55·3	·820	6
September	56·3	53·5	2·8	51	·852	5
October	51·6	49·1	2·5	46·6	·846	6
November	45·5	43·7	1·8	41·4	·878	6
December	39·9	38·5	1·4	36·5	·898	5·4
Means	50·2	......	......	44	·844	6·6
1850.						
January	34·9	34·1	·8	32·9	·932	7·3
February	44·6	42·6	2	40·2	·863	7
March	40·4	37·8	2·6	34·2	·815	5
April	48·4	46·2	2·2	43·6	·854	7
May	51·6	49·6	2	47·6	·871	6·6
June	59·5	55·1	4·4	51·6	·778	4·4
July	61·6	58·4	3·2	55·8	·836	6·8
August	59·5	57·4	2·1	55·7	·888	6·5
September	56·3	53·8	2·5	51·6	·865	5·1
October	46·6	44·2	2·4	41·3	·840	5·5
November	47·1	45·1	2	42·7	·867	6·1
December	42·8	41·7	1·1	40	·920	6·9
Means	49·4	......	......	44·7	·861	6·2
1851.						
January	44·5	43·3	1·2	41·7	·917	7

TABLE IV.—Wind.

1848.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Force.
February	8	4	1	1	3	9	36	5	1·4
March	15	1	1	6	15	1	14	7	·8
April	14	11	2	6	11	2	9	5	·6
May	5	7	9	10	19	5	6	2	·5
June	0	6	2	4	10	15	18	5	1·
July	3	11	1	1	10	13	17	5	1·
August	4	3	1	2	5	5	41	2	1·
September	5	13	6	4	16	5	11	1	·4
October	4	4	1	2	10	17	8	2	·7
November	11	15	1	1	4	5	17	6	1·
December	4	3	...	2	14	12	8	2	1·1
Sums	73	78	25	39	117	89	185	42	·8
1849.									
January	6	11	2	6	4	9	19	5	1·1
February	2	2	1	5	3	13	20	9	·3
March	9	15	1	7	5	8	11	7	·2
April	7	14	1	12	5	6	5	5	·3
May	11	11	1	6	6	7	7	4	1·1
June	14	16	5	3	5	3	10	1	·1
July	6	4	6	2	9	16	15	4	·3
August	4	10	...	3	6	17	12	7	·2
September	3	13	7	4	8	14	4	4	·2
October	7	13	4	1	8	14	9	3	·2
November	9	9	3	10	9	9	7	4	·1
December	17	7	3	3	5	8	5	8	·3
Sums	95	125	34	62	73	124	124	61	·37
1850.									
January	19	10	5	8	2	5	8	6	·5
February	8	...	1	...	2	21	15	7	·5
March	26	9	2	...	5	7	3	6	·2
April	9	6	3	3	13	12	3	2	·6
May	13	8	4	2	9	13	5	3	·3
June	5	2	4	6	9	12	9	5	·2
July	15	3	1	3	12	4	13	4	·3
August	13	3	...	1	14	10	17	2	·3
September	7	16	5	5	9	3	6	5	·3
October	14	15	2	2	1	5	13	10	·3
November	9	4	1	1	2	18	12	3	·4
December	3	1	6	7	8	13	4	8	·3
Sums	141	77	34	38	86	168	108	61	·35
1851.									
January	2	...	6	6	10	16	6	1	·5

TABLE V.—Differences between the Readings of a Thermometer near the surface and another one foot below.

1850.	Therm. at the surface.	Therm. one foot below the surface.	1850.	Therm. at the surface.	Therm. one foot below the surface.
January	35·8	35·4	July	69·5	61·3
February	45	40·8	August	66·1	59·1
March	45·8	39·2	September	63·7	54·5
April	54·4	47	October	51·1	47·1
May	58·7	47·8	November	47·4	46
June	68·8	61·5	December	41·1	40·8

TABLE VI.

Comparison of the Climate of different Localities.

	Number of days when the temperature fell to 32° or below.				Number of days when 0·5 in. of rain fell, or more.				Amount of rain in inches.				Number of days on which rain fell.				Mean temperature.			
	Southampton.	Falmouth.	Stone.	York.	Southampton.	Falmouth.	Stone.	York.	Southampton.	Falmouth.	Stone.	York.	Southampton.	Falmouth.	Stone.	York.	Southampton.	Falmouth.	Stone.	York.
1848.																				
February	9	3	12	8	3	5	......	1	4·821	6·6	2·7	4·2	24	24	10	19	43·3	46·2	41·9	40
March	6	1	12	4	......	1	......	2	3·431	4·1	3·3	3·3	23	23	24	23	45·1	46	42·4	41
April	3	1	8	7	1	2	......	......	3·175	4·3	2·4	1·4	15	18	16	20	48·4	49·2	47·1	45·6
May	......	......	......	......	......	......	......	1	·701	·9	·3	1·1	4	5	7	7	58·4	56·4	57·2	57·2
June	......	......	......	......	4	2	1	5	6·694	3·6	3·1	7·4	18	17	20	21	58	56·6	58·3	57·1
July	......	......	......	......	1	3	2	......	2·750	3·5	1·5	1·7	15	13	......	15	62	59·7	60	60·8
August	......	......	......	......	2	2	......	2	5·118	5	2·6	3·2	23	25	27	19	59	59·5	56·4	55·8
September	......	......	......	......	1	2	3	2	3·108	3·1	4·6	4·1	12	12	16	11	57	58·9	53·9	53·9
October	......	......	1	2	2	......	1	1	4·208	2·8	3·6	4·6	22	19	23	23	51·8	53·2	48·9	46·8
November	10	1	9	8	2	1	......	......	2·581	3·6	·7	1·1	12	20	16	10	42·7	46·7	41·1	40·3
December	5	1	6	10	3	3	1	1	5·025	6·7	2	2	18	19	12	14	44	47·2	42·4	39·4
Sums and Means	33	7	48	39	19	21	8	15	41·712	44·2	26·8	34·1	186	195	171	182	51·8	52·7	50	48·9
1849.																				
January	9	......	16	12	1	2	......	......	3·170	4	......	1·6	18	26	......	18	40	46·2	......	37·4
February	6	......	12	9	......	3	1	......	1·382	3·4	......	·5	9	14	......	5	43·1	46·2	......	40·3
March	4	2	......	6	2	......	......	......	1·285	1·2	......	1·1	9	14	......	11	43·1	45·6	......	40·2
April	......	......	7	6	1	1	1	......	3·337	3·2	2·8	2·	22	20	21	18	44·5	45·4	41·9	41·5
May	......	......	1	......	3	1	1	......	2·626	2·5	3·8	2·	8	12	17	14	58	53·6	52·5	50·7

June	......	......	......	......	......	2	......	......	·992	2·3	1	1·1	6	11	13	8	60·1	56	56·6	53·6
July	......	......	......	......	3	......	1	2	3·128	·9	2·2	3·3	11	10	12	15	60·3	59	60·6	57·4
August	......	......	......	......	......	3	......	1	0·451	3·2	1·1	2·3	6	17	13	11	60·7	60·7	60·1	57·2
September	......	......	......	......	5	3	......	......	4·531	6·6	3·2	2·5	10	14	21	11	56·6	58·4	55·4	53·4
October	......	......	5	3	3	1	......	1	5·614	3·1	2	2·4	15	15	18	16	51·3	53·4	49·4	45·5
November	4	......	8	10	1	4	......	1	1·709	3·9	1·3	1·9	11	18	11	13	45·1	50	42·5	40·4
December	13	8	13	17	2	3	......	......	4·773	4·3	1·9	2·8	14	20	14	20	39·3	43·4	38·3	35·6
Sums and Means	36	10	62	63	21	23	4	5	32·998	38·6	19·3	23·5	139	191	140	160	50·2	51·5	......	46·1
1850.																				
January	22	9	28	28	......	......	1	......	·892	3·5	1·2	1·6	6	18	6	14	34·4	41·1	32	32·1
February	1	......	4	5	2	2	......	......	3·037	3	1	·5	12	14	14	16	44·2	47·8	42·8	41
March	15	3	15	14	......	......	......	......	·238	1·2	·2	·5	4	9	6	7	39·6	44·6	37·9	37·2
April	......	......	1	......	5	2	1	......	4·731	4·2	2·4	2·1	20	18	14	16	48·5	45·5	47·1	45·1
May	......	......	3	......	1	1	......	......	2·265	3·7	1·7	·7	12	14	20	16	52	50·8	49·4	48·6
June	......	......	......	......	2	......	......	......	3·099	·9	1·3	1·7	9	9	9	10	59·4	58·5	59·1	57·5
July	......	......	......	......	4	2	2	......	4·298	3·2	2·9	3·1	15	10	17	14	61·9	60·4	60·4	58
August	......	......	......	......	......	1	......	......	1·974	2·7	1·3	2·2	10	12	15	16	59·8	59	59·1	56·8
September	......	......	......	......	1	3	......	......	2·830	4·9	1·6	1·1	8	11	14	8	55·9	57·9	53·9	52·4
October	4	......	3	4	......	1	......	......	1·629	2·3	1·5	1·7	11	13	21	18	46·4	50·7	45·1	45·5
November	6	......	8	7	4	3	1	......	4·794	4·6	2·2	1·9	12	20	18	13	46·9	50	44·5	44·4
December	7	4	13	13	1	3	......	......	2·557	4·5	1·9	·8	9	15	17	11	42·4	47·5	39	37·7
Sums and Means	55	16	75	71	20	18	5	......	32·344	38·7	19·2	17·9	128	163	171	159	49·3	51·1	47·5	46·4
1851.																				
January	2	......	9	7	3	3	1	......	5·4	7·3	3	2·1	21	28	20	18	44·5	46·6	41·4	41
Aggregates & Means	126	33	194	180	63	65	18	20	112·455	128·8	68·3	77·6	474	577	502	519				

On the Air and Water of Towns. Action of Porous Strata, Water and Organic Matter. By Dr. ROBERT ANGUS SMITH, *Manchester.*

It is becoming daily more important to find out from what source it is best to obtain water for great towns, and by what means it is to be collected. It is probably true that a mode of supply suited to the conditions of all parts of the country is not to be our direct aim, as every town must have its supply modified by its own peculiarities of position, but it has still to be settled what water is preferable when there is a choice before us. I have here put together a few facts and reasonings which seem to me to deserve prominence, and which have not, as far as I know, been sufficiently dwelt on.

Water has been got from rivers and small streams, sometimes from the surface drainage of ground, and from deep wells and springs. The use of well-water is the first that is resorted to where there is no stream or spring, and where the inhabitants are not too many to be satisfied with such a source. The water from this mode of supply is often exceedingly pure and brilliant, according to the nature of the filtering-bed; but as most soils have a good filtering-bed underneath, want of cleanness is not a common fault of wells. There is in fact a proverbial purity about springs and wells; and mountain streams frequently share in receiving the same character from the literary and poetic observers of nature. It is interesting to know how this purity is attained. There are many springs which never become muddy, which possess a constant brilliancy, which never become cool in winter and never warm in summer. They seem to be unaffected by what is going on at the surface of the ground. From this it appears that there is a purifying heat-regulating action going on beneath. The surface-water from the same place, even if filtered so as to become clear, has not the same purity, *i.e.* the same freedom from organic matter or the same brilliancy; neither has it the same amount of carbonic acid or the same quantity of oxygen in it. There are influences therefore at work, under ground, which are not at work on the surface.

The rain which falls has not the same purity, although it comes directly from the clouds; it may even be wanting in cleanness, as is often the case; it may be nauseous to the taste, and be wanting in carbonic acid and in oxygen. It never has the brilliancy of the spring water, nor is it so free from organic matter. For these reasons all the world has admired spring water. The mountain streams have had their share of admiration, and sometimes they equal the spring water. Spring water and well water are of course essentially the same; both have passed through a considerable depth of soil. The well has been dug in order to convert a portion of the surrounding ground into a filter, and in order to make a depositing place for the water which trickles through. The spring has made its way through similar passages, sometimes easily traced, and has the advantage of coming to the surface clear, without any such accidents as may occur to disturb the purity of a well. In many parts of the country these springs are hard; they often go through a great extent of soil and collect a considerable amount of inorganic salts, varying, from the strong solutions found at celebrated watering-places, to the milder form of a few degrees of hardness. Whilst the inorganic matter increases with the depth of the flow of water, the organic matter decreases, and may be said entirely to disappear. This is accomplished even at a depth not very great. It always happens, except when the well is not sufficiently sheltered from the surface-water, either from the soil being too porous in proportion to the depth, or from the surface-water having in some way a too ready passage into the well.

In examining this matter, I have been struck with the numerous cases

of this kind which happen in country places; the well is put in a garden or back yard, and often very little defended. The number of cases of sickness from these causes is, I am inclined to think, greater than is believed. Although it is not my province to examine the matter in a medical point of view, I have had opportunities of perceiving, partly alone, partly in conjunction with medical men, that there are constantly occurring cases which seem to be brought on or aggravated by the state of the wells. The impurities which occur in the country wells are chiefly organic matter. This is known by its decomposition, a small amount producing a disagreeable smell and taste, and at the same time a dullness in the water, so that it makes itself known to us by three of our senses. If it is merely surface-water somewhat cleared by standing still, it will make itself known by depositing a great amount of green vegetation, when a little is allowed to stand in a clear bottle. The remedy for this evil is not difficult, and probably very well known. It consists in defending the entrance of water into the well in such a manner that the water shall be filtered. If a well be badly supplied with filtering material, the use of sand will make a good filter, placed round the well so that the water may pass down and bubble up like a spring from the bottom. In the country the organic impurity may be easily removed in this manner; but in the town, or near cesspools and similar places, the impurity, if removed, leaves behind it an unfortunate result,—the formation of nitrates and increase of chlorides, and often of other salts, chiefly of lime. This water may be perfectly clear and often is brilliant; and some people do not discover a nauseous taste until the solution of salts becomes so strong as to give the water the sluggish flow of oil. So little is the taste of good water known in a town, that water, which to an ordinary taste was nauseous and almost painful, has been in use for years by people who might rationally have been expected to know better.

This complete nitrification and thorough removal of the organic matter occurs chiefly in town wells, the complete change being much less frequent in the country; the cause of this lies, no doubt, in the slower and more thorough filtration, and therefore the more elaborate cleansing when passed through a hard soil, and in the removal of the rain-water by surface-drainage or by sewers before it is allowed to weaken the solutions by being absorbed into the soil. The amount of organic matter which is removed or altered in this way is surprising, and the power of effecting this transformation is a most important and valuable part of the functions of a soil. Of course the same change takes place in country places, in gardens, for example, well ornamented and not well drained, where the water has much organic matter in solution and stands long on the soil. This change takes place very close to the cesspool or to the source of the flow of organic matter, and at a very short distance water may be found containing very little besides inorganic salts. Very near a sewer, in one of the worst streets in Manchester, I found sand which was almost free from organic matter, although the drain had given way and was allowing the sand to absorb whatever it could. The same observation was made on the sand of a churchyard in which burials were very frequent, showing the great advantage of a porous soil in removing offensive materials by an agency within itself, preventing the corruption of the atmosphere to an extent greater or less, according as the powers of the soil are under- or over-taxed.

As an agent for purifying towns this oxidation of organic matter is one of the most marvellous, we might almost say, and necessary. If the impure organic matter were taken underground by the natural flow of water, the state of the subsoil would become pestilential in the extreme, and towns could not be inhabited without such careful drainage as we have never yet seen;

in fact the soil would require to be impenetrable. To inhabit a place for a few months would be to make it unhealthy. Instead of such a result, we have the soil of towns, which have been inhabited for centuries, for a time longer than history can tell us of, in a better state than the soil round many a country-house. St. Paul's churchyard may be looked on as one of the oldest parts of London, I suppose; the water there is remarkably free from organic matter, and the drainage of the soil is such that there is very little if any salts of nitric acid in it. A well at Tower Hill was in a similar condition, but not so thoroughly nitrated. Of course there are parts of a town where the matter becomes too great to be managed well, and being combined with bad drainage, even the active state of the subsoil, which seems to do its utmost to destroy all the elements of disease which enter into it, is not sufficient to remove the amount continually supplied to it from some hundred acres of closely-built ground. Even in these cases however we are more surprised at the comparative purity of the subsoil than at the impurity. As it is, the impurity of the subsoil in certain parts of towns requires proof; and although proof can be got and is got, without this action of the soil the proof would stare us all painfully in the face and hunt us out of its vicinity. It has become necessary to prove the great amount of evil resulting from burial in towns, whilst the enormous amount of organic matter has disappeared rapidly from our view, and the evil seems only to become distinct to us when the mould of the churchyard has become in a great measure the remains of organized beings.

If soil has such a power to decompose by oxidation, we want to know how it gets so much of its oxygen, and here there appears a difficulty; we must, however, look at once to the air as the only source, and see how it can furnish the supply. When water becomes deprived of its oxygen, it very soon takes it up again. If water be deprived of its oxygen by the use of sulphate of iron, so as to make a white precipitate of protoxide of iron, or if it be deprived of it by boiling, and a little white precipitated protoxide of iron placed at the bottom, it will be found that a few minutes will give some colour to the iron. It will pass through the blue and almost black stages to the yellowish brown, taking the oxygen from the water, which again supplies itself from the air, and is in fact a kind of porous medium for the gas. This shows us readily how the soil may be oxidized, how the nitric acid may be formed under the surface of town soil. We do not in fact find it formed at great depths, but we find it formed in undrained places which have no other source of oxygen. It may seem a trifling matter to explain this, but it was a difficulty to me to see how the oxygen could be collected in some of the almost subterranean circumstances in which it accumulated. Water from wells in a soil like this, continually obliged to force oxidation, is sufficiently objectionable, and it requires no eloquence to deter people from using it when they once know it. Perhaps, however, when the nitrates are in not very large quantities, when they cannot be tasted, the water may be reasonably considered much better than any water with matter in it liable to putrefactive decomposition, and the general testimony of tradition is to consider it so.

It appears, in fact, that organic matter is incapable of passing deep into a soil; by conversion into soluble salts it becomes soluble, and by that means it is easily washed away in an inorganic state. When this occurs in the country, the use of it is not so apparent as when it occurs in a town. When there is a great excess of organic matter on the surface of the ground, it does of course decompose, and the results are bad for health; and if ammonia is formed too rapidly, bad also for the soil, which loses its food for plants. The formation of nitrates prevents the passage of nitrogen into the atmosphere, it

subjects the soil however to a loss by drainage. The use of nitrates as a manure has long been known to be valuable; our old English philosophers have been well-aware of it, for example, Boyle and Bacon. Before the nitre can be formed in the soil, the ammonia must be oxidized; and before it can be used as food for plants, the process must be reversed and it must become deoxidized. The oxygen thus stored up may then readily be applied for rapid oxidation when this is wanted, and in this way it becomes a kind of concentrated atmosphere, a source of air by which to form carbonic acid from the mould of the soil. We can readily view it as a great stimulator of vegetable life, besides being a source of nitrogen to feed the plants. In dry climates, perhaps it might be viewed as a supply of water, as we might readily consider it formed by the union of the oxygen with the hydrogen of substances in the ground. The organic matter in a soil may be supposed to decompose in two methods, by the formation of ammonia and of nitric acid. If the soil is very alkaline and moist, the conversion of the organic matter into ammoniacal compounds is very rapid. I put some soil, not very rich in organic matter, into this condition by the assistance of a little ammonia so as to make it alkaline, and the consequence was the rapid occurrence of a very intense putrefactive decomposition, not in any way differing, as far as could be perceived, from that of ordinary putrefaction of animal and vegetable matter. These nauseous and unwholesome odours are therefore possible from the ordinary soil of our fields; but any occurrence such as this on a large scale would be disastrous, and the ground is protected from it by an almost constant acidity, which sometimes increases so as to be injurious, forming what is called sour land. This very acid state generally occurs in wet land, where it is probable that alkalinity would be most injurious, but the soil may be found alkaline in a well-manured garden and where the ground is dry without apparent injury. The other mode in which the organic matter may decompose is by the formation of nitric acid, the nitrogen obtaining oxygen indirectly from the air, and so providing against the excess of ammonia which might readily occur in certain soils, producing results which would be fatal to animal life, if not provided for by an enormous vegetation. At the same time it does seem reasonable to suppose that the cause of a diseased climate may frequently be found in such a decomposition as that mentioned, when too much ammonia has been formed, or too little nitrogen has been removed by the formation of nitric acid. All the circumstances may be found for the purpose, abundance of nitrogen compounds and moisture; even a warm climate is not essential. And it also seems reasonable to suppose that the formation of nitric acid is one of the means by which such evils are avoided, whether in town drainage, where it becomes evident from the great amount found, or in the imperfectly drained and rich, although not swampy lands of tropical climates, where the large amount of nitrogen, if converted into ammonia, would no doubt produce the worst effects.

Water alone on soil often becomes too saturated with organic matter for use, and either attacks also the living plants, or induces circumstances which forbid them to grow. Let us suppose the soil dried up; the decomposition would cease, and the nitrates formed would come out in efflorescence. Let us suppose it not dried, but kept constantly moist and cold, and we have the ground in a state described in a very interesting manner by Bernardini Ramazzini, producing a disease which is not unlike the potatoe disease with us, and although perhaps not directly bearing on my subject, may yet come in by a natural association. A wet and mild winter in the territory of Modena was followed by a summer of a similar kind, and "the sound of the grasshopper gave way to the croaking of frogs." The crops were destroyed and

the fish increased in such quantities as was not before known on any previous year, so "that Neptune, instead of Ceres, supplied food" to the country. About the beginning of June there appeared on vegetation a form of *rubigo*, a rusty withered appearance; the same disease had occurred the year before, which had also been very wet, although in a less degree. This disease increased in spite of all prudential care, beginning with the mulberry and attacking afterwards the beans very fiercely. This began in low putrid places, but it afterwards made its way into elevated situations. He says, "Luctuosum sane ac deplorandum spectaculum omnium oculis fuit, campos circumquaque non virentes, sed atratos ac fuliginosos intueri. Anno præcedente, rubro colore, hoc anno non *creta* sed *carbone* notando." "It was a melancholy sight and painful to every one to look on the fields, which, instead of being green and healthy, were everywhere black and sooty. The former year might be marked red, but this year must be marked, not with white, but black.". . . . "The very animals returned the food which they had eaten, it was so nauseous . . . . the sheep and the silk-worms perished . . . . the bees went timidly to work with their honey-making . . . . the waters became corrupt and fevers attacked the inhabitants, chiefly the country people, such as lived in the wet lands."

If the rain falls on land where plants are decomposing it will not be fit for domestic use, unless passed through strata deep enough to clear it; and water of this kind, although not so bad as that described at Modena, will be found more or less to make up rivers which surface-drain rich lands. This water is always liable to deposit a large amount of green matter, and often in great quantities, with abundant animalcules. One may even tell this kind of water by burning the residuum from boiling; if it has a vegetable odour, it will after a time deposit vegetation and animalcules interspersed; if it has an animal odour, having much nitrogen, the animalcules will be of a different kind; if it has a peaty odour only, having no albumen, it will produce little or no deposit. It becomes therefore a matter of great importance, when examining waters for use, to find what becomes of them after standing awhile. To say how much organic matter is in them is not enough, but it is important to know its quality. This difference of quality is the most important thing to know; suppose a specimen having merely humus in solution or crenic acid, an analysis would put it in a very inferior condition to a specimen of water having organic matter from rich fields, which water had never passed through the soil, or water which had passed by towns and had in it matter from the town sewers. The first would be shown by mere chemical analysis to be the worst, having a larger quantity of organic matter; the result by standing would show the superiority. Water may pass by towns, and after standing a little be very clear; if kept still longer and in a suitable place, it will deposit its impurities in an organized state; it may be filtered again, and again deposit impurities. The matter is in solution; and very clear river and other water is often found in this condition. It is therefore most important, as an element in the appreciation of water, to find the amount of *organizable* matter in it.

The water from rivers which have run far is apt to contain salts of various kinds, besides those contributing to hardness, and in this they seem to agree with water from cultivated land. This would agree also with the deep drain-water from cultivated land, so far as inorganic salts are concerned. If water contains lime as a carbonate, the hardness and the amount of lime ought to be the same. This occurs at the sources of the Thames, where, in two instances, the hardness was rather greater than the whole amount of inorganic matter. This is to be accounted for by the excess of carbonic acid

decomposing a little of the soap used to test for hardness. These waters came out of the inorganic strata direct: the difference in this respect may be seen by the following specimens:—

	Inorganic matter in a gallon.	Hardness.
Drain 4-feet deep, near Manchester	8·4	4·2
Another on the higher grounds, less cultivated land and shallow drain	5·6	3·75
Another on bog-land	7·	3·75
Water near the soil	30·8	7·47
Well at Stretford near Manchester, badly-drained garden land	20·	11·22
———, another near it	29·7	15·5
Thames at London Bridge	29·06	15·5
From an underground street-cistern	43·05	15·5
Thames at Oxford	17·25	16·
Thames at Seven Springs	12·25	12·75
Thames at Andover Ford	13·3	13·88

Higher up the river the extraneous salts diminish as well as the ashes of the organic substances. The best-drained land (the first two) has very little in excess, but the badly-drained land has a great deal in excess. The underground cistern, with many impurities, may be looked on as water of very badly-drained land, and is the worst; it was taken from a court in London. There might be many instances given of the same kind from wells and elsewhere.

If we take the excess of inorganic matter over hardness, we shall have:—

	Excess of inorganic matter over hardness. grs. per gallon.
4 foot drain	4·2
Shallow drain in poor land	1·85
Bog-land drain	3·25
Water near the soil	22·33
Stretford, 1st.	8·72
Stretford, 2nd	13·2
Thames, London Bridge	17·
Cistern in London (underground)	27·55
Thames, Oxford	1·25
Thames, Seven Springs	0·5 below.
Thames, Andover Ford	0·58 minus.
Thames, at Kemble	·6 above.
Chelsea, filtered	8·528
Windsor	6·51
New River	6·46

Apparently then the difficulty of obtaining water free from impurity increases as we go down a river, and as we come to cultivated land. The deep drain-water of cultivated land, although having more inorganic matter, is not in other respects to be objected to. I have several specimens, which, after standing a long time, have deposited organic matter only in very minute quantities, and are in fact equal to well-water of considerable depth. The organizable matter seems to have been removed, although the organic matter is not entirely removed, the only thing remaining being some of the highly carbonaceous compounds of the soil. Its superiority over river-water, which consists often of drainage water from the mere surface, cannot therefore be questioned, except when the river-water itself is composed of the under-drainage of a country, or the drainage of such barren tracts as give off little organic matter, or readily part with it.

There is a not very distinct idea common enough with regard to water, that it decomposes or becomes putrid. Now, properly speaking, this cannot be; it is entirely unchanged in all situations; but as a vehicle for impurity, it may be said in popular language to become putrid. Water does not become putrid therefore in any sense but this, that the matter which it has in solution becomes decomposed; this putrefiable matter is obtained by the passage of the water over the soil or out of the soil at a depth not sufficiently great for its removal. Sir Humphry Davy says, "Common river-water generally contains a certain portion of organizable matter which is much greater after rains than at other times, and which exists in largest quantity when the stream rises in a cultivated country." A good deal of this matter is in very fine suspension, and without making it appear very turbid takes away at least from the brilliancy of the water. To give instances will be unnecessary; water taken from the surface and allowed to stand, and water from a deep well, or water taken from a drain which runs clear, may be compared easily by any one. The soil contains an abundance of organic matter, but the under soil contains little or none, diminishing as we go down. The line of demarcation between the organic and inorganic portion of the soil is very distinct; if water be filtered through the upper soil even for a great length of time, the organic matter is not removed from it; it will even be dissolved out, whereas the soil immediately below it has first very little and then no organic matter in it, whilst the constant draining downwards does not drag down to it the soil of the surface; the two remain distinct portions of the organism, so to speak, of the soil. The use of this is also sufficiently clear; in growing, the plants require that the food should be in solution, and the water dissolves it; but when it passes away the plants require that it should leave the food behind it, and accordingly it leaves it.

Although the soil is acid, it is worthy of remark that waters flowing from soils, river-waters and well-waters are alkaline, made so by lime-salts generally, and also by magnesian and alkaline salts. It is remarkable with what rapidity the lime is dissolved, and how steadily the hardness of the water is preserved at one point for years. The acidity of the soil must first be neutralized by the lime, and an additional quantity be then taken up, the lime compound being retained in the filtering medium, and the organic matter thereby prevented from removal. But the power of the soil to retain matter does not depend on any mere formation of insoluble compounds, on alkalinity and acidity; but entirely on the action as a filter on what may perhaps be termed its mechanical power, although it is not purely so.

To show this, a solution of peaty matter was made in ammonia; the solution was very dark, so that some colour was perceived through a film only the twentieth of an inch in thickness. This was filtered through sand, and came through perfectly clear and colourless, having still a great excess of ammonia.

Acetic acid was added to it until it became acid; this solution was perfectly clear (I may mention that acetic acid does not dissolve it if used first); it passed acid through the filter of sand, and became colourless.

Thinking to try the power of such a filter, I dissolved some organic matter in strong sulphuric acid, to see if the strength of the acid would not act as a counter agent to the great decomposing power of the sand. The acid was allowed to pass through almost pure, although the depth was only about four inches.

The same was tried with muriatic acid, which was black by the mixture of some organic substance; it passed through the sand rapidly, and was in fact brilliant.

Sometimes, if the purifying is not completed by merely passing through

the sand, it is completely done by simply allowing it to stand in contact with the sand. This would seem to indicate that the action was in a great measure, if not entirely mechanical; at the same time it is not an action which takes place in a moment; some time is required for it.

If the water is driven too rapidly on it will not be filtered, and wells in wet weather often indicate this by becoming turbid. It is true that becoming turbid is different from discoloration, but the particles which are carried forward by the water are frequently those which have organic matter in them, as may be shown by the deposit on standing. Time, however, is wanted; as a continued standing with the sand shows, and as the slow percolation through soil also shows, the purification is most complete when the passage of the water is continued for some time. A case was related to me by a gentleman who had attempted to filter beer through a barrel of sand and charcoal; the filter was too strong for it, and it came through pure water. I may add, from my own experiments, that a bottle of porter after standing some time was made into a bottle of something like ale, the dark colouring matter quite removed, and the taste nearly destroyed.

The material of the filter is also of inferior importance; one of the best filters which I have made, as far as clearing of the water is concerned, was of steel filings; the water was of course rather a chalybeate. Oxide of iron and oxide of manganese made very good filters; pounded bricks also, as far as clearness is concerned, and mere removal of colour from the water.

Filtration, therefore, has another object in view besides the mere straining through a substance, the pores of which are not sufficiently large to allow the larger pieces to pass. The removal of organic matter in solution is one important object, as well as the formation of nitrates in some conditions. The passage through the soil is very slow, and the complete act of filtration has time to be elaborated. We sometimes see water flowing from land having only a slight moisture visible in it, and we see from whole acres a mere dropping from the drains. We know, too, that water is kept close in contact with surfaces, so much so as to give us the idea of very great force. It will not pass through a porous substance unless its place is supplied by other water; it will not keep its level in such situations as it does in a free state. We may imagine, then, the great amount of surface with which it must come in contact, moving slowly through acres and sometimes miles of soil.

Mere freedom from matter in suspension is got very readily by the use of fine porous substances; the upper soil itself will take away matter in suspension; and peat will do so readily, sometimes without giving any colour to the water. Mere fineness of pores is not therefore what is wanted, as the finest part of the soil is uppermost.

Rivers have often a brown colour, arising from clayey particles in union or in conjunction with organic matter; that is, the water in these cases, if allowed to stand, does not deposit mere mud, but also organized bodies, the same circumstances which bring one, bringing also the other. Motion through soil with fine particles in it requires to be slow, otherwise there is turbid water formed. It is remarkable how bright most of the chalk waters are; although hard, the chalk removes the fine substances that are so often found suspended in water like small hairs, or in an invisible form, causing only a dullness of appearance. This mechanical action is not difficult to procure, as even in a laboratory the most brilliant solutions are obtained by the use of paper only. Some substances are readily filtered out; others are very difficult to filter, and some cannot be filtered; some will not filter in water, but will readily in acid. There does appear to be an action by which a substance

attracts all the impurities in water, or envelopes them in itself, as alum or albumen or lime is used to clear water, but I don't see any of these acting to cleanse the streams to any extent.

The decoloration of water is not so striking on cultivated land, because the colour is not so great; but the colour on the hills which are covered with peat is of a deep brown, and it is curious that we have from such places the finest water.

I have observed in several places that where the brown streams have been led into reservoirs on the top of the hill, or on the sides of the hill, or even at the bottom of the hill, these reservoirs have continued brown. The canal also from Leeds to Manchester is brown, although the water is brought down a considerable distance. When these streams are led through artificial conduits or pipes, they do not become colourless; at least the Sheffield water, although it may clear itself to some extent on the way, is still delivered in the town of a decidedly peaty colour. It is believed that plants obtain carbonic acid by the oxidation of humus and analogous substances; but it is difficult to believe that in the course of a few miles so much oxidation should take place on the surface of a stream as to remove colour. Many of the streams come out pure from the hill, and, although from a bed of peat of great thickness, are brilliant and colourless. These hills may be found covered above, and in all hollow and flat places, with water which is of a deep brown colour, and strong taste. It has been said that the purification is made by the dashing among the pebbles and mingling with the air, but the most highly-aërated water is not found in these streams. If this were a very important agent in purifying a short water-course, the streams would have around them an atmosphere of carbonic acid, or they would sparkle with increased beauty as they proceeded, until they bubbled with carbonic acid. I have never traced a stream in this state of purification; there is generally an influx of other water from various points which influence its purity, and which probably contribute more to it than the action of the air. It is curious, too, that the streams are brighter in summer, although the water dissolves more peaty matter; for then stronger solutions of peat are to be found on the hills and in some streams.

The water, however, may often be observed in the act of being cleared. On the top of a hill we see a swamp over which it is difficult and indeed impossible to pass without sinking deep enough to become wet; we go round it, and on every side it is dry. Very often there is one side depressed with a passage for the water down the hill. This passage is often wet all the way down; the water collects from all sides and forms into a stream. I shall describe a pretty common case as I have observed it at Tintwisle. There was no perceptible passage of water from the swamp, although there was an easy natural flow whenever the water rose high enough to take that mode of discharging itself. This bed, if it may be so called, was at the time I examined it quite dry; under the turf there was coarse gravel, the surface of the white siliceous rock being considerably broken. The water in the swamp above was very brown; going further down there issued from the side of the hill a stream of pure water; the water came from the swamp through the gravel, and went down the side of the hill pure; before getting down it was lost again, entirely disappearing through some more gravel, but it made its appearance again still lower down. It was nearly lost a third time by going into some grass land, which it made very swampy, before it got finally down to the main brook. There was no want of an opportunity to clear itself; the space was not above a few hundred yards in which it sunk twice and re-appeared. After having seen this, I began to find that it was common; I found two streams near together, each draining a considerable amount of wet land on a hill near Buxton, and disappearing

entirely, after beginning their flow down a narrow gorge which they seem to have made for themselves. On walking up these streams, which were of a considerable size, each was found to disappear; the bed of the streams became entirely dry, although it could be seen that they were very often filled high with water. On going a little higher the streams appeared again, with a taste of peat, which they had not below. Afterwards I began to find that the disappearance of a stream which was wonderful in fable, was a very common thing on these hills. Of course perfect purity is not found in these cases; the last traces of organic matter are only removed by passing through great depths or long standing.

Again, by observing the manner in which a stream collects water, this disappearance, however common, may be seen not to be essential to the filtering of a stream. On the sides of the stream the water may be observed oozing out of the soil at the lower points, sometimes very slowly, so as only to give an appearance of moisture to the side; but when this is continued the whole length of a stream, the increase of water becomes plain. The actual point of egress of the water from the soil into a stream which is purified, is, I conceive, under the upper soil, and the water is in reality filtered, whilst there is an accession of water from every point of both sides of the stream.

This will in a great measure explain how a stream becomes colourless by mere running; if it has come off the grounds without filtration, as is sometimes the case, especially with the higher streams, by getting too readily into a channel, the water is mixed with other water, oozing into it on every side, and thus the filtered water mixes with the unfiltered; that water which comes further down the hill before entering the channel, being most likely to come through a filtering bed. Water flowing over unbroken and impervious rocks could not become purified in this way; it could not be subjected to any action but the ordinary influence of the air. It would not, however, be necessary for the purification to be entirely confined to those cases; a modification of them is found when water flows down a hill through the sand or gravel under the soil, in which case it may break through the soil, or trickle through the subsoil, as occasion offers. The mere passage upwards through the soil, in the manner of a spring, will not give it impurity, unless it be very slow, as in this case it does not much come in contact with it.

This mode of natural purification would indicate that a reservoir for the supply of pure water should not be put on very high ground, such as at Blackstone Edge, or in fact so high that these natural processes should be interfered with. It might lead us also to a mode of collecting, which has not, as far as I know, been adopted, to drain the ground in such a way as not merely to collect the water, but to filter it at the same time. When the rains are heavy, the water does not follow any of these courses spoken of, and runs over the surface, falling into streams without becoming filtered, and taking down a great deal of matter in suspension. This could not be prevented probably when there is a great amount of water; but in ordinary cases it might be so hemmed in as to prevent it flowing away except through a filtering medium. In some cases this would be very easy, where the water flows very gradually out of a mass of peat. No filtering beds would be required, and little if any attention. In looking over a large extent of sandy district in Surrey slightly covered with heath, I was struck with the fact, that the upper sand, wherever it was bared, was washed white; it was also white wherever it was on the surface, although sometimes mixed with peat so as to give it a dark colour, until the peat was washed off. The under-sand, however, was of a yellowish or reddish colour, caused by oxide of iron. The acid from the peat had washed away all the iron out of the sand, and left the colour of the silica pure,

whilst even a few inches below there was no colour removed from the sand. There was another circumstance to be mentioned, that the water coming from the lower strata had no taste of peat, whilst that coming from the upper strata had. The whole surface might be taken as an instance of a great filtering bed; but it is very remarkable that the filtering did not appear to be gradual, but instantaneous; the sand did not gradually become redder on going down, but it was red at once, and did not change. The organic matter seems to be removed at a certain point, and not to go below it. A few inches below the soil there was to be seen a black band running all along the country, I might say, and I dare say most persons will have seen something similar where peat lies on sand. The blackness was evidently caused by a constant deposit of dark peaty matter on the point of filtration, as it may be called. There were cases in which the water flowed over the bare sand, and then the blackness was on the surface of the sand; where there was vegetation, it was below the roots. This black matter along with the sand looks like a sand and charcoal filter. The same may be seen to a less extent on land which has not been ploughed up for some time, a mark running along under the soil where colouring matter seems to have been deposited. We may very correctly look on the soil as the greatest agent for purifying and disinfecting. Every impurity is thrown upon it in abundance, and yet it is pure, and the breathing of air having the odour of the soil, has, on what evidence I don't know, but evidently with truth, been considered wholesome. Whatever may be taken up by the soil the water is discharged clear, and although vegetation does its part, we do not wait the return of the season to remove impurities from the air above the soil; they are laid on in autumn, but do not disturb us. The purity of drainage water has been observed long ago, so that I do not pretend to advance a novelty; and we find in Loudon's Cyclopædia of Agriculture, that "Marshall, seeing the formation of natural springs, and observing the effect of subsoil drains, and being at the same time aware of an objection to roof-water, which, though more wholesome, is seldom so well-tasted as spring water, was led to the idea of forming artificial land-springs to supply farmsteads with water in dry situations. He proposed arresting the rain-water that has filtered through the soil of a grass ground situated on the upper side of the buildings, in covered drains, clayed and dished at the bottom, and partially filled with pebbles or other open materials, thus conveying it into a well or cistern, in the manner of roof-water, and by this means uniting, it is probable, the palatableness of spring water with the wholesomeness of that which is collected immediately from the atmosphere."

Besides this action of the soil, there is the chemical action by which wells get filled with carbonic acid; and water percolating through underground strata becomes aërated by oxygen or by atmospheric air, and thus nitric acid is formed. It is known that many substances in the act of decomposition cause the union of oxygen and hydrogen, and in doing this some of the oxygen is used for the formation of carbonic acid. This is a sufficient source of the carbonic acid found in water, where time and opportunity is given, such as in passing through deep strata; and when we suppose it pressed into the water by the mechanical force, such as is found in capillary and surface action, we have in nature a close resemblance to the artificial plan of preparing soda and aërated waters. Sharp sand has been found to be most suitable for the passage of water, and sharp pieces of glass have been found to cause the union of oxygen and hydrogen more readily, and at a lower temperature than rounded pieces. If the wells get their carbonic acid in this way, that is, from the decomposing organic matter, the very impurities of the soil become the greatest elements in purifying the water, and in rendering it palatable

and sparkling, as well as dissolving rocks, and making those various solutions which we often find difficult to imitate. At the same time we must infer that the purest water is a great agent in removing the vegetable matter from the soil, in the form of carbonic acid, and that it is not essential that the carbonic acid should rise directly from the soil, or that plants should be placed on the spot to consume it. It has never been the custom to add oxygen to any of the aërated waters; but although very little is absorbed, it would probably be a very useful imitation of the natural process to add that gas in addition to carbonic acid.

Rain-water has often been asserted to be the purest of all water, and if falling on siliceous rocks it must still remain pure, as they have very little soluble matter to impart. This may be the case in some districts, but the probability is against it, as rain is a mode of removing impurities from the atmosphere; and for the large towns in Lancashire, and similar places, there can be no reliance placed on mere rain-water. Collected in a town, we know it to be a nauseous and black liquid; and when we go a mile from a town it is no less nauseous, although it loses its blackness. This would show that the black soot from chimneys is deposited very near a town, although the soluble substances are carried further; and it may be observed, that in wet weather the smoke falls more rapidly, from the soot becoming heavy with moisture, as well as from the change of the barometer. Even many miles round a town the rain is unfit for use, without being passed through purifying materials. I have tried it as far as ten miles from Manchester; and it is probable that it is nowhere free from objection, as it has been found necessary to take means to render it palatable even in agricultural districts. But this same water having passed through sand or rock comes out brilliant and in every respect good, being purified by the natural process. For this reason, as has been often remarked, the water springing out at some depth is much superior to that lying on the surface.

Even rain-water standing for a time gives indications of organization, which is not the case with deep water. Although the water which does not come from a great depth does contain more organic matter than rain-water, it has gained other advantages sufficient to overbalance that fault; if, indeed, the small amount of organic matter found in water from sandstone can be looked on as a disadvantage. As the washing of the air seems to be one of the duties of rain, it is not surprising that some mode should be again employed by nature to purify the rain. The action of the soil for this purpose seems to be a necessary completion of the process. Dew does not exhibit the same extent of impurities, no doubt arising from the limited space in which it is formed whilst the rain passes through a large extent of air.

As the use of surface-water has been so highly recommended, I have thought it well to state the valuable qualities of a good filter, and the mode in which I believe the best water is produced. This I believe to be by filtration, which, even more than distillation, removes the organic matter, and more than any known method, improves the taste and the appearance. As the rain-water has washed the air, and the deep well-water has brought with it solutions of degraded rocks to a large extent, both seem objectionable; and as the surface-water carries along with it matters of all kinds in solution and suspension, according to circumstances, it seems more advisable that the water which has been purified by passing not too deep under the surface should be used, since all the advantages and all the peculiar powers of filtration are found in that portion of the ground.

Report of the Committee appointed by the British Association to consider the probable Effects in an Œconomical and Physical Point of View of the Destruction of Tropical Forests. By Dr. HUGH CLEGHORN, *Madras Medical Establishment*; Professor FORBES ROYLE, *King's College, London*; Captain R. BAIRD SMITH, *Bengal Engineers*; Captain R. STRACHEY, *Bengal Engineers.*

As preliminary to the Report which your Committee has now the honour to submit, we have to make the following remarks. The great extent of the subject prescribed to us, involving as it would have done, if completed in its integrity, the collection of materials from every tropical region on the surface of the globe, would have involved an amount of labour which we had neither the time nor the means of devoting to the subject. Three of our members had special duties required from them, which did not admit of being in any way postponed*, and it has been consequently on the fourth (Dr. Hugh Cleghorn) that almost the entire labour has devolved of collecting and digesting the materials now laid before you†.

The personal relations of the whole of the members of your Committee with the Tropical Region of British India, naturally suggested to them the propriety of limiting their researches to that field wherein they had themselves been employed, and with the circumstances of which they were not only best acquainted, but had also the best means of filling in any imperfections which might exist in their knowledge. The subsequent report has accordingly reference solely to the Forest Question as applied to India, and we have endeavoured to collect all such information as would illustrate the physical and œconomical effects of the destruction of the natural woods, which in that, as in other countries, are of such admitted importance.

In reference to the physical effects of the removal of forests, we found considerable variety of opinions. There is, it must in fact be admitted, a deficiency of *exact* or experimental information on the subject. Observations of a *precise* character on climate in countries once covered by forests but now cleared, do not to our knowledge exist, and the evidence with which we have to deal is a kind of evidence which admits of considerable variety of interpretation. Of such evidence we have exhibited a number of examples, and the general conclusions which appear to be warranted by these may be perhaps best given in the following words of Humboldt, the most eminent authority who has discussed the question:—

"By felling trees which cover the tops and sides of mountains, men in every climate prepare at once two calamities for future generations—the want of fuel, and the scarcity of water.......Plants exhale fluid from their leaves, in the first place, for their own benefit. But various important secondary effects follow from this process. One of these is maintaining a suitable portion of humidity in the air. Not only do they attract and condense the moisture suspended in the air, and borne by the wind over the earth's surface, which, falling from their leaves, keeps the ground below moist and cool; but they can, by means of their roots, pump it up from a very considerable depth, and, raising it into the atmosphere, diffuse it over the face of the country. Trees, by the transpiration from their leaves, surround themselves with an atmosphere, constantly cold and moist. They

* Professor Royle has been engrossed with the Exhibition and his other duties. Capt. Baird Smith has been employed on duty abroad, and Capt. Strachey was digesting his own Himalayan researches for the press.

† In drawing up the Report, it was necessary to alter and compress the language of the original documents; but care has been taken to give the opinions of the authors as nearly in their own words as possible.—H. C.

also shelter the soil from the direct action of the sun, and thus prevent evaporation of the water furnished by rains." In this way, as Humboldt states, the forests contribute to the copiousness of streams.

The question as between the maintenance and removal of forests appears to us to be a question of compensations. Wherever the progress of population requires that every portion of the soil be made to yield its quota of human food, there the destruction of forests is to be desired, and the disadvantages to which want of wood for social and general purposes may lead, must be compensated for, as they doubtless will be, by the ingenuity which is born of necessity. But there are localities in nearly all countries to which the tide of population can never flow, but where the forest can flourish, and where it ought to be maintained. To tropical countries, the preservation of the springs which feed the rivers, on which the fertility of the land and the prosperity of the people are so essentially dependent, is of the greatest importance. These springs rise in the mountain regions where forests prevail, and it is to such regions that a protective agency should be extended, for there can be but little doubt that the entire removal of wood leads to the diminution of water. In a single sentence, we would say that where human exigences, whether for subsistence or for health, require the destruction of forests, let them be destroyed; but where neither life nor health is concerned, then let a wise system of preservation be introduced and acted upon.

The planting of such trees as are desirable from the fruit which they afford, or grateful from the shade which they yield, is an act which has been held in high esteem in eastern countries, especially India, from very early times. The eastern appreciation of the luxury of shade led to the banks of the canals, constructed by the Mahommedan emperors, being planted, and the waysides of the imperial roads being lined with trees of various kinds; in the Sunnud of the Emperor Akbar, it is directed, "that on both sides of the canal down to Hissar, trees of every description both for shade and blossom, be planted, so as to make it like the canal under the tree in Paradise; and that the sweet flavour of the rare fruits may reach the mouth of every one, and that from those luxuries a voice may go forth to travellers calling them to rest in the cities where their every want will be supplied*."

But the planting of trees for timber seems to have been neglected there, as it has been in most other countries, until modern times. This is no doubt owing to self-sown forests being more than sufficient to supply all the wants of man in the earlier states of society. As population and civilization are advanced, such forests are looked upon rather as impediments to agriculture, than as sources of wealth, and the means of removing trees are more thought of than the readiest modes of propagation, or how they should be treated so as to produce the best timber in the shortest time, and in the fullest quantity that the ground is capable of bearing, and so managed that it may yield some profit even while the timber is growing†.

British India is so extensive an empire, so diversified in soil and climate, as well as in natural and agricultural products, that it is impossible to predicate anything respecting it generally; that which is descriptive of one part, is not necessarily applicable to another. Thus some parts are covered with primæval forests, as the mountainous coasts of Canara and Malabar, the country surrounding the Neilgheeries, the Tenasserim Provinces, much of Central India, the base of the Himalayan Mountains from Assam up to the

* Calcutta Review, No. 23.

† The substance of the above and following paragraphs is extracted from a valuable MS. Report of Dr. Royle on the advantages of increased planting in certain districts of India.

banks of the Ganges, as it issues from the hills, and beyond it; while other parts are not only bare of trees, but even of vegetation of any kind, as the deserts which run parallel with the Indus, and stretch more or less into the interior of India. The North-western Provinces, as well as many parts of the Peninsula of India, are generally bare of timber-trees, as are also the highly cultivated Southern Provinces of Bengal. But in most parts of India clumps of trees may be seen by the traveller in every direction in which he can look. This is owing to the Indian practice of embowering every village in a clump or tope of trees, generally of the Mango, but frequently the Bur, Peepul, Tamarind, &c. are found, some yielding fruit, others grateful for their shade, and some yielding fodder for elephants and camels. In the neighbourhood of every village also may be seen tracts of jungle, more or less extensive, which by some are accounted so much waste land. They are often composed of long grass, or of low shrubs, as the Dhâk and wild Jujube, with a few trees intermixed, as the Babool and Seriss. These tracts, though disfiguring the rich appearance of a cultivated country, are far from useless, as they form the only pastures which the natives possess for their cattle, as well as their whole source of supply for firewood, and whatever timber may be required for the building of their huts or the making of their agricultural implements.

From the number and extent of the forests and jungles of India, it might be inferred that timber was abundant in all parts, not only for home consumption, but that a supply might be obtained for foreign commerce: this is far from being the case. Though forest lands are extensive, their contents in accessible situations are not of a nature, or sufficiently abundant, to supply even the ordinary demands. In India, as in other long inhabited and early civilized countries, the parts best adapted for agricultural purposes have long been cleared of jungle. The forests lying nearest to the inhabited tracts were first stript of their timber, and as no precautions have been taken to replace the old trees, a gradual diminution has been observed in the supply of timber, which has consequently increased in price (as may be seen in the Government contracts for building and the Commissariat outlay for firewood), not solely from actual deficiency, but because timber is only obtainable from less accessible situations, with considerable increase of labour and expense.

As the principal cities where the greatest demand for timber exists are in the centre of cultivated tracts, so are they necessarily remote from the forests from which they require wood, either for the construction of houses and machinery for ship-building, or other purposes. Hence a commerce in timber has long been established in India. Calcutta and the cities situated on the Ganges are supplied with timber grown in the forests which skirt the foot of the Himalayan Mountains, from Assam to the banks of the Jumna. These supplies are floated on rafts down the numerous feeders of the Ganges, which forms the great artery of the plains of India. But this is not sufficient for the consumption of Calcutta, as considerable quantities are imported from the Burman Empire. In the same way there is an insufficient supply for the Madras Presidency, which is made up by importing timber from Ceylon.

Bombay has long been celebrated for the building of ships with teak-wood, supplied from the forests of Malabar and Canara, whence timber seems always to have been exported even to Arabia and Persia.

Looking at the extent of India, and reading of its interminable juugles, it may seem a work of supererogation to talk of the deficiency of timber or of the necessity of protecting its forests. Timber to be valuable must be of the

proper kind, of the proper age, and at proper distances, that is, in accessible situations. As might have been expected, from continual drains being made on these forests, without adequate measures having been adopted to keep up the supply, a continued and increasing deficiency has been experienced in all parts of India, which has frequently attracted the attention of the Indian and Home Governments, so that in the Bombay Presidency numerous reports have been made on the state of the teak forests, and measures adopted for their improvement, without as yet much benefit.

In the Madras Presidency steps have at different times been taken to encourage planting, as in the time of Dr. Anderson; and lately we have seen the Madras Government applying annually to Bengal for the seeds of Saul and Sissoo, for planting in Madras. These have been very successfully introduced and acclimated in the territories of Mysore and other southern provinces. In a letter from Capt. Onslow to Dr. Cleghorn, dated Shemogah, 21st July 1847, that intelligent officer writes in reference to a plantation on the banks of the Toombudra,—"I have never seen any vegetation so wonderful as that of the Sissoo; last year's seedlings are almost too large to transplant. It would be a pity to allow the monsoon to pass over without putting in more seed." The Mahogany (*Swietenia Mahogani*), a tree of great value and beauty, has been introduced successfully into the Calcutta Botanic Gardens, and a few specimens are thriving at Madras and in Mysore, giving promise of its being nearly equal to the finest varieties from the Honduras. Specimens of furniture prepared by Dr. Wallich from trees grown at Calcutta are now in the museum at the India House.

Dr. Wallich was despatched in 1825 to the Upper Provinces in order to inquire into and watch over the extensive forests of the empire, which were found to be undergoing most wasteful and rapid decay. Three MS. volumes of reports and proceedings, with two original maps of the route taken by Dr. Wallich and Captain Satchwell, were placed by the Supreme Government with the Agricultural and Horticultural Society "*for information and deposit.*" These volumes contain the labours of a body of public officers, which, under the denomination of "THE PLANTATION COMMITTEE," originated under the administration of the Marquis of Hastings and continued in existence six years. The records of its proceedings, as contained in these volumes, extend over 1070 pages of manuscript. They contain much and most valuable, indeed generally unknown information, bearing on the great practical measure of forest cultivation, the Sissoo localities in particular; and every effort should be made to rescue this information from oblivion. The late Dr. Spry, Secretary of the Agricultural and Horticultural Society, was desired to undertake the examination of these records, and favour the Society with a report upon their contents. He devoted much time to this duty, and reported in July 1841, that the really valuable part of these papers might be condensed into a small-sized volume of about 250 pages. The work of condensation, that is the compilation, so as to avoid the official forms in which the information is introduced that the matter may be brought into a continuous form, will necessarily be great, and require that some specific allowance be made for its performance. The carrying out of this proposal was committed to Dr. Spry, and had his life been prolonged, would have been executed by him. We regret that the fulfilment of his intentions has not devolved upon any of his friends, considering the importance of giving publicity to such valuable information, and we still think the matter deserving of recommendation to Government. Dr. Wallich has borne testimony to the value of the information, and stated that if the undertaking be

sanctioned, he would be most happy and willing to give his valuable assistance in the work of publication.

"The reports of Dr. Wallich are particularly valuable respecting the natural forests, both of those within the British territories in India, and also those of the neighbouring powers. In his visit to the Turai, or low and moist forest-land skirting the base of the Himalayas, he particularly recommends a vast extent of forest-land in Oude, situated on the east side of the Kowreala river, as holding out the prospect of very valuable supplies, provided that means are adopted for preventing wanton destruction and of allowing the young plants to grow up and supply the place of those which are cut down. Among the forests in our own provinces, Dr. Wallich adverts particularly to those occupying the Islands of the Gogra, commonly called Chaudnee Choke. He represents them as extremely important, and in every way deserving of being preserved for the exclusive use of the Government, and especially of being emancipated from the destructive depredations which are annually committed. The Sissoo and Saul forests of the Deyra Doon are also recommended to be preserved for the use of the service; though from these the facility of transportation is represented as not equal to that from the other quarters previously mentioned. But they are nevertheless as important for the stations in the north-west of India, as the forests of Oude and Gorukpore are for those in the south. As considerable deficiencies of timber, at least of those kinds usually employed, such as Saul and Sissoo, besides Bamboos, had been experienced, and as the deficiency every day increased, Dr. Wallich was induced to recommend that Government should interfere in the management of the forests; for the natives, from their extremely injudicious mode of felling forests, cut and carry away all that are easily accessible, both young and old plants, without planting any thing new in their place, or encouraging the growth of the young seedlings. Another great defect in the native mode of managing timber, is their total neglect of any regular system of seasoning:—timber ever being seasoned by them at all, depends upon the proprietor not having been able to sell it."—*Royle's Prod. Resources of India*, p. 189.

The glory of the Malabar and Tenasserim forests is their teak, the vast importance of which is becoming daily more known and appreciated; the timber indeed has been long prized. Bontius described the tree under the name of *Quercus Indica*, though except as regards the timber it has no resemblance to the Oak. Rhæde has given an accurate representation of *Tectona grandis*, and refers to the teak forests of Malabar in these terms (Hort. Malab. iv. t. 27):—"Crescit ubique in Malabar, at præsertim in provincia Calicolan (Calicut) ubi integræ sylvæ ingentium harum arborum reperiuntur.* * * Lignum vero hujus arboris quercino ligno haud absimile, operi fabrili accommodum, atque naupegis ad navium fabricam in usu est: sed in aquis (præsertim dulcibus) teredini facile obnoxium."

It will be shown that these large forests, supplying the *finest sort* of teak, had fallen long ago into a deplorable state, both old and young trees having been indiscriminately cut down, without regard to future supply.

"This work of destruction," according to John Edye, Esq. (As. Soc. Journ. ii.), "is conducted by a company of Parsee merchants, who take a certain number of the natives from Mangalore at the proper season for felling, and, without consideration for the future, cut all sorts of peon-spars, saplings as well as large trees, to the great injury of the forests. There were hundreds of small spars from five to nine inches diameter, and thirty-five to seventy-five feet long, actually decaying on the beach at Mangalore at the

time I was there; from which circumstance in the course of a few years these valuable forests must be exhausted. The whole of this trade is in the hands of a combined party of these people, who never fail to take advantage of any particular demand that may occur."

In Wight's 'Illustrations,' vol. ii., just received, he remarks,—"The timber of the *Tectona grandis* is about the most highly esteemed in India, that of nearly all other trees is spoken of as jungle-wood and inferior. Time does not now permit, otherwise some remarks might have been offered on the subject of the preservation of the teak forests, and the recent fearful waste and destruction of that valuable, I had almost said invaluable, tree in all our teak forests, without a single step being taken either to keep up the stock or preserve young trees from the ruthless hands of contractors and others, licensed to cut teak timber. Measures are now, I believe, in progress to arrest the ruinous destruction that has for some years been going on, and it is hoped that the Directors will succeed in their object; otherwise the stock in hand will soon be exhausted."

The following extract is from a private letter of Dr. Macfarlane, late Zillah Surgeon, Mangalore:—

"For the Canara forests, I can testify from personal observation as late as December 1849, that Coomree clearing was being carried on to a most destructive extent in those tracts surrounding the falls of Gair-soopah. As far as I could get any information on the subject from Lieut. Walker of the Engineers, who is employed in the district of Canara, and with whom I visited an extensive Coomree inclosure near the Deva-munny Ghaut, no check seems to be exercised over the forest population in this respect. Lieut. Walker's description to me was, that the jungle people ringed the trees to kill the large ones, took the branches and made a fence against wild animals, burnt as much as they could, and then took one or two crops of millet (or ragee) out of the soil, going over to another tract and repeating the same practice. All around in that primæval forest, thousands of acres were, or had been, evidently under *Coomree*, the large timber-trees destroyed, the spaces left blank in the forest, and in all these Coomree spaces that had again been left to nature, I could not help remarking that wild plantains invariably sprang up in myriads."

The extensive forests of teak mentioned by Buchanan in his 'Journey through Mysore in 1800,' have well nigh disappeared, as will be seen by the details in the following Report:—

"Nuggur Division, Superintendent's Office, Shemoga,
5th May 1847.

"To the Secretary, to the Commissioner of the Government of the Territories of the Rajah of Mysore.

"Sir,—In connection with the subject of my letter of the 11th March last, there is another, unquestionably of great importance, now occupying the attention of the Government of India, and which I am confident will at once engage the attention of the Commissioner,—I allude to the conservation of the forests as regards timber, the value of which might with care and attention be made very important in Nuggur. From want of these nearly all the fine teak and other timber which once flourished on the banks of the Toonga and Bhudra rivers have disappeared, and the Government has derived but very little benefit from it.

"2. Vast quantities of various kinds of timber are yearly carried down the Toongabhadra river to the open country, by people who pay a small sum to the farmer of the forests for the privilege of cutting it. In the months of August and September these people take down hundreds of floats made of

bamboos loaded with timber. Teak, black-wood, and ebony are forbid to be cut; but I am well assured that these prohibited timbers are taken away in great quantities every year; we have no means whatever of preventing it.

"3. The forests are rented yearly to the highest bidder; the renters, holding their farms for a year only, have no interest in preserving the forests; on the contrary, their interests are best served by their destruction. They make their profits by taxing the timber-cutters and coomri cultivators; therefore the more jungle there is cut, the greater are their profits. The consequence of this indiscriminate cutting is the total disappearance of teak in localities where it formerly abounded, especially in the vicinity of the river Toonga. Buchanan in his 'Journey' says at vol. iii. p. 287, 'Here (*i. e.* between Teerthully and Mundagudda in the Cowledroog Talook) were many fine teak-trees, more indeed than I have ever seen in any one place. They might be of value could they be floated down the Toonga to the Kerishna, and so to the sea.' This is after he had seen the Soonda and other fine forests in Canara. When at the same place in February last, I saw no teak, and I saw none the whole length of the river as far as Mundagudda.

"4. There is some teak remaining in the forests near Mundagudda about twenty miles from this, but it is fast disappearing, and in a few years there will be none within the reach of the river. Teak is occasionally cut on account of Government, brought to Shemoga, and sold; but it does not bring a good price. The average amount of sale for the last five years is Company's rupees 181 6, as is shown in the accompanying statement, which exhibits also the average of each item of revenue, the produce of the forests for the same time, and a total average of Canteroy pags. 1168 5, or Company's rupees 3397 4 2 annually.

"5. This is all the revenue that the magnificent forests of Nuggur are made to yield by the present system, which is fraught with mischief. There is no preservation of the timber that stands, nor encouragement of the growth of young trees; and at the present rate of destruction there can be no doubt that in a few years there will be no valuable timber left in places from which it can be carried away.

"6. But this is by no means the only evil: Coomri cultivation is mischievous in various ways. The following are some of the most prominent objections to it. It causes the most rapid destruction of the forests, which, it is a well-ascertained fact, lessens the quantity of rain and moisture, and must thus, in the course of no very long time, seriously affect the cultivation and prosperity of the country. The cultivation of the Mulnaad* is solely dependent on rain (there being no irrigation), and requires abundance of it. The people of the Mulnaad begin already to remark that there is a diminution of rain; and I think it highly probable that it is attributable to the vast extent of Coomri clearings all over the country, but especially along the crest of the Ghauts. Looking over Canara, immense tracts of Coomri are to be seen as far as the eye can reach. Some weeks ago I went down the new Ghaut leading from Hunnaur, above the Ghauts, to Colloor in Canara, and was much struck with the immense extent of Coomri. I saw tens of thousands of acres cleared on the hills. The new pass is six miles long, and is entirely through clearing, where not a single forest-tree is left standing. In these clearings, the primæval forest, with all its beautiful timber and valuable productions, has given place to a thick scrub of noxious weeds and brambles, containing nothing useful. It may be supposed that clearing the forest would make the country more healthy, and so it would if the clearing were more permanent; but the forest is now destroyed only to be replaced by a thick

* *i. e.* Rain-country.

jungle of rank vegetation, still more unhealthy than the forest, which being open below, admits of circulation of air; but the scrub is a dense mass of vegetation, and from bottom to top it is about twenty feet high. But however this may be, I think it is a question worthy of serious attention, whether the present unlimited destruction of the forest shall be allowed to continue, risking the diminution of rain, the effect of which would extend over the whole of the southern part of the peninsula, and perhaps occasion most disastrous consequences.

"7. More inland, Coomri cultivation is destructive of much sandal-wood. There is now a case under inquiry in the Shikarpoor Talook, in which eighty trees have been destroyed. The average value of a sandal-wood tree is from five to fifteen rupees. In the coffee districts this system is very objectionable. Coffee will not grow in a Coomri clearing, the soil having been exhausted, and the fires in the neighbourhood of plantations endanger it. The Coomri cutters would be much better employed in the plantations. Upon a representation of these objections, I forbid Coomri in the Chickmoogloor Talook some months ago.

"8. This cultivation has great attractions to the lower classes of cultivators and labourers; it leads numbers from the cultivation of the beriz-lands, and thus directly injures the revenue, and produces in those who take to it lawless and vagabond habits. Along the Ghauts the Coomri cultivators, when not engaged in their cultivation, employ themselves in smuggling, which the clearings and their knowledge of the country greatly facilitate. In the Mulnaad a trifling rent is paid to the forest-renter. In the open Talooks a low rent is paid directly to Government. In either case the payment of it is often evaded by those who have clearings in remote and inaccessible parts, where they are not easily discovered. The cultivation is of the rudest and simplest mode. The trees are felled in January and February, and allowed to remain in the ground till the next season, when they are burnt. The earth is not turned at all, and the seed, ragee, castor-oil, or dholl*, is thrown broad-cast upon the ashes among the stumps. The crops thus produced are always abundant. Formerly the practice was to take only one crop, and leave the clearing, which allowed the stumps to shoot out again, and the same spot would bear cultivation again after from twelve to twenty years. But of late the practice of repeating the process the second year has grown up. The same clearing will bear cultivation again after from twelve to twenty years: when it has been cultivated for only one season the stumps of the trees shoot out again if only once cut and burnt; but if this is done a second year, they perish, root and branch, and the spot is ever after productive of nothing but scrub. The soil has been totally exhausted, and produces nothing but weeds. It is probably this practice, which did not formerly exist, that has caused such extensive destruction of the forest.

"9. Coomri cultivation is therefore directly injurious to the revenue; it has a demoralizing effect upon a great number of people, and is in all respects objectionable, except under the circumstances explained in the following paragraph. The renting system is unproductive of revenue, and destructive of the forests; I am therefore of opinion that it ought to be abolished, that the forests should be kept in the hands of Government and preserved, and that Coomri should be altogether forbidden, except under strict supervision, and the orders of the superintendent.

"10. There are some parts of the country where clearing the jungle might be done with great advantage in many ways. There are extensive ranges of jungle composed of bamboo and stunted trees, which are quite unproductive,

* *Eleusine coracana*, *Ricinus communis* and *Cajanus indicus*.

and the clearing of which I would encourage. The people might be taught to clear and cultivate the land in a way which would not be destructive of its powers. There are immense ranges of this kind of jungle between Chickmoogloor and Belalryandroog, and in the Luckwolly Talook, to the west of the Bababooden Hills, which produce nothing whatever, and are very unhealthy. In other parts, more to the east, there are similar jungles, which produce sandal-wood. In these, Coomri could be allowed, care being taken of the sandal-wood. It is along the Ghauts where I think Coomri is particularly objectionable; there the forests are composed of fine timber-trees, hold many valuable productions, and are perfectly healthy; and it is there where the formation of rain would be most affected by clearing the forest.

"11. To bring out the value of the forests, not only should that which exists be preserved, but considering the vast importance of its timber, teak should be planted, as is done in other parts of India. Hearing of the successful planting of teak in Malabar, I applied to Mr. Conolly, the collector, for information, and he has been kind enough to send me a memorandum of his method of planting, which he tells me is most successful; I am confident that the same could be done in many parts of Nuggur, in the most favourable positions along the banks of the Toonga and Bhudra rivers, where teak grows spontaneously, and where, from the facility of transportation afforded by the river, it would become very valuable. I annex a copy of the memorandum I have received from Mr. Conolly. I have collected a quantity of teak-seeds, and Dr. Cleghorn undertakes to raise seedlings here, which I purpose to plant as an experiment along the banks of the Toonga, between Shemoga and Mundagudda, where formerly teak grew large and abundantly.

"12. Should the Commissioner sanction my proposal to preserve the forests and form plantations of teak, it will be necessary to keep up a small establishment. Perhaps the following would be sufficient for the present:—One Darogha on 6 rupees per month, and twelve Carnatties on 3 rupees. It is desirable not only to plant young trees, but to facilitate the growth of the spontaneous seedlings by clearing away obstructions. Buchanan remarks on this subject in the same paragraph that I have quoted above, 'I know of no place that would answer better for rearing a teak forest than the banks of the Toonga, where close to the river there is much excellent soil which is considered as useless, as there are on the spot many fine teak-trees. All that would be required would be to eradicate the trees of less value, which I look upon as a necessary step to procure any considerable quantity of teak in a well-regulated government.' This remark is perfectly applicable to the locality I have in view, which is twenty miles lower down the river than the place he alluded to.

"I have, &c.,

(Signed) "W. C. ONSLOW, *Superintendent.*

"'The depredations of wood-cutters seem to have suffered no check until the last year, and I fear the means taken are still very insufficient to prevent indiscriminate havoc. To give you some idea of the waste of valuable and ornamental timber in this country, I will just mention what I discovered at Hydrabad. I was in want of light-coloured wood for picture-frames, and applied to the regimental contractor: what was my surprise to find that every third or fourth log in his great store of firewood was most beautiful satin-wood of large size! Only imagine the victuals of a whole regiment, not to say of a large community, being cooked with satin-wood! On this fact becoming known, applicants for the satin-wood became numerous. I consider it nearly equal to the bird's-eye maple for ornamental work.'

"'CAPT. HARVEY, *in literis.*'"

In the following extract of a letter from Dr. Wight to Dr. Cleghorn, dated Coimbatore, 3rd April, 1851, it is well observed,—"As to the destruction of forests, it appears to me that there can be but one opinion on the subject, and that is, that it is most injurious to the welfare of any country, but especially of a tropical one, and ought upon no account to be tolerated, except where the ground they occupied can be turned to better account, and even the entire denudation should be avoided. I am not yet prepared to admit that trees have the property of attracting rain-clouds, and thereby increasing the quantity of rain that falls; but there can be no doubt that they increase the retentiveness of the soil, and moreover keep it in an open absorbent state, so that in place of the rain running off a scorched and baked soil as fast as it falls to the earth, it is absorbed and gradually given out by springs. I am not prepared to go so far as to say, that forests, especially on high hills, have not the effect of attracting rain-clouds, but I am quite sure that if they to ever so small an extent have that property, the benefit is augmented a hundred-fold by their property of maintaining an open absorbent soil.

"On this ground it is that I should like to see this country extensively planted, especially on all the elevated lands, because water absorbed in elevated grounds forms springs in the low ones: you truly say, that short-sighted folly has already done much mischief, and the Ryots have suffered to an immense amount. This is most true, but the difficulty is to put the saddle upon the right horse. Who has done the mischief?

"Within about fifty miles of the spot whence I write, a tract of country has been cleared; the result is that the inhabitants are now so much distressed for the want of water that they contemplate leaving the country, their wells being all dry. On inquiry, it does not appear that the rains have fallen below the usual average, but notwithstanding, the country has become so dry that their wells no longer provide a sufficient supply of water.

"Major Cotton, from whom I have the information, attributes it to the rain running off the baked soil as fast as it falls, in place of sinking into the earth and feeding springs. The subject is now attracting attention, and doubtless before long it will be ascertained whether forest has the effect of augmenting the fall of rain, or whether it results from the increased capacity of the soil for moisture. If the former, it is to be hoped that extensive plantations will be had recourse to as a means of equalizing the monsoons; and if the latter, that it will be adopted as a means of retaining the water that falls from the clouds."

Concerning the vast forests on the opposite side of the Bay of Bengal, the principal observers, so far as we can learn, have been Wallich, Helfer, Griffiths, Blundell, Seppings, and O'Riley.

Dr. Helfer, who has written a Report on the Tenasserim Provinces, speaks of the Teak as furnishing one of the greatest riches of the country, and being the foundation of all those improvements which have followed our acquisition of it. He informs us that many trees perish by bad management; that many trees which are killed are not found subsequently fit for use; that they are suffered to decay, and generate a host of insects, which attack good trees before they are seasoned, and that much timber is wantonly destroyed. "The same negligence of the natives which reigns throughout the country with regard to wanton destruction of the forests by fire, extends equally to teak forests; and I saw extensive tracts utterly destroyed, because it was the pleasure of some wild Karean to fix his abode in the vicinity, and for this purpose to clear the jungle by burning all down.

"As teak is such a valuable article in general, and it may be safely asserted,

hitherto the only one to which Moulmein owes its daily increasing prosperity, the preservation of teak forests should be the principal care of government."

The following observations are extracted from a paper by Mr. O'Riley, in a recent number of the 'Journal of the Indian Archipelago:'—"At the head of the vegetable productions of spontaneous growth of these provinces, the Teak of its extensive forests holds the most prominent place; forming as it does, the only staple article of commerce that has as yet undergone any degree of development, and upon which the interests of the port of Moulmein have arisen and steadily progressed to their present scale of importance.

"Many obstacles oppose themselves to the attainment of an accurate knowledge of the actual resources of the teak localities; the most important, and the only insuperable one, being the excessive unhealthiness of the forests, which possess an atmosphere loaded with malaria, and fraught with fever to all persons unused to its baneful influence. Since the demand for teak-timber for the home market has been created, it will be apparent from the following statement of the exports from 1840 to 1848, that the quantity to be obtained is fully equal to the demand for it; and this is more evident from the circumstance of there being at the present time a stock of rough logs equal to 15,000 tons of converted timber, which has not yet passed the general department, the absence of a demand preventing the holders from paying the duty upon it.

Exports of teak-timber for the years from 1840 *to* 1848 *inclusive.*

1840	4,952	tons.
1841	6,399	„
1842	11,487	„
1843	10,528	„
1844	14,245	„
1845	13,360	„
1846	16,798	„
1847	11,250	„
1848	18,000	„

To which may be added 3415 tons appropriated to ship and house building, and other purposes, giving a value at the rate of 40 rupees per ton of Company's rupees 869,800 as an annual amount derivable from this commercial staple of Moulmein.* * * * For the due encouragement of the timber trades in the first instance it was deemed advisable to grant licenses to cut teak within certain ill-defined limits to parties connected with the trade of the place, which teak, on its arrival from the forests, was subjected to a certain rate of duty.

"For the preservation of the forests, certain terms were demanded by Government from the holders of licenses, to the effect that trees below a standard size were to be left, and for each full-sized tree felled, a stated number of young trees were to be planted, the latter from experiment having been found to be impracticable. With so frail a tenure, it might have been anticipated that the holders of such licenses, perhaps without any large amount of capital available for forest purposes, would endeavour to realize the largest possible amount of benefit at the least possible outlay, *without reference to the ultimate productions of the forests*; hence the system of sub-letting supervened, as being the most congenial means to the end; and the result of such measure has been the working of the forests by Burmese, who receive an advance on a contract to pay to the holder of the cutting-license the half of the timber on its arrival in Moulmein. To the same cause must be assigned the reckless destruction of property, which has become a system in the extraction of the timber from these forests. Many of the trees

being of the largest size, and admirably adapted for ships' masts, are for the sake of convenience and expedition in their transport to Moulmein, cut into lengths of more manageable dimensions, say from fifteen to twenty cubits, and in this form of log depreciate the value of the original spar to *one-tenth* of the amount it would have realized as a ship's mast! No excuse can be admitted in extenuation of this defective process of working the forests: the most powerful and effective animal power, in the shape of elephants (which are in general use in the forest work), is abundant and cheap, and if to that power the simplest European mechanical appliances were systematically applied with ordinary skill and management, the British navy might be masted from the teak forests of these provinces.

"Whether it be found expedient to reserve the forests as a government property exclusively, or on the other hand, granting right of property in perpetuity to the holders of forest licenses on certain well-defined terms, and thereby enlist their pecuniary interest in the preservation of the tree, and improvement of their grants,—whether either of the foregoing form the basis of the ultimate measures of Government, it must be evident that in the establishment of a well-organized system of administration instead of the present obviously defective one, permanent good must result.

"The subject of teak-timber has claimed the attention of several public journals of late, in consequence of some disclosures made in the proceedings of the Government dock-yard of Bombay, and *all are unanimous* in directing attention to it as a most important commodity, demanding the most stringent legislation to secure supplies for the future from the British possessions equal to the growing demand for it, as a staple, thus noticed by the 'Friend of India':—'The amazing durability, we might almost say indestructibility of teak, renders it not only one of the most valuable, but *the most valuable wood*, in a climate like that of India, where the elements of decay are so numerous and powerful, where dampness brings on rapid corruption, and the white ant devours without scruple.'

"The principal trees of Tenasserim are the following, some of them classed by Dr. Wallich in his notice of the forests of these provinces:—

1. Anan.
2. Thengan, *Hopea odorata.*
3. Peengado, *Acacia.*
4. Bambwai.
5. Pumah, *Lagerstrœmia.*
6. Kouk Kmoo.
7. Padouk, *Pterocarpus.*
8. Theet Kha.
9. Toung Baing.
10. Yin dick, "a bastard Ebony."

"The foregoing are the most generally known woods of the forests in common use with the natives, but to them might be added a list of forty or fifty others more or less useful, which require but a careful examination to reveal some quality that may render them of serviceable application. Of the remaining forest trees and shrubs which possess valuable properties, the following are those most adapted to a demand for European consumption; but owing to that absence of commercial enterprise already noticed, are at the present moment all excluded from the list of exports in Great Britain.

Dyes.

Sapan-wood	*Cæsalpinia Sapan*	Teni-yeit.
Jack-wood	*Artocarpus integrifolia*	Pemgnay.
Red-dye	*Morinda citrifolia*	Neepatsay.

"Of trees and plants possessing odoriferous properties those forming articles of trade are as follows:—

Native Name.
Kurrawa........ *Laurus Sassafras* ...... Sassafras.
Kenamet ...... *Santalum* .... Bastard Sandal-wood.
Thee-Kye-bo.... *Laurus C.* .... Wild Cinnamon.
Akyan....... A very fragrant and a very scarce wood, of high value with the natives.

"The oil-producing trees are—

Ten-nyeng and Eing; both of the class Dipterocarpus, and
Theet-Tyee, producing the black varnish peculiar to the Burman territory, and of which the lacquered ware in general use is made.

"The Tavoy province, from the large number of wood oil-trees found in its forests, supplies the whole of the provinces with materials made from the oil, &c.

"The other known forest productions, which in quantities would form a valuable acquisition to the exports of these provinces, are,—

Gamboge, produce of Tha-nahtan, *Garcinia elliptica.*
Camphor, " Blumea.
Balsam tolu.
Cardamoms.

"The trees producing both Gamboge and Balsam tolu, are unequally dispersed through the jungles, and are comparatively scarce; the gamboge predominates, and might afford a considerable quantity of the article, did the knowledge of its value and the process of collecting it exist with the Karens; the tree however is felled indiscriminately with the rest of the forest in the annual clearings for upland paddy, and vegetable plantations, and an article which forms a prominent item in the rich exports from Siam, is on this side of the border range utterly neglected and destroyed.

"The most common weed which springs up after the fires of the new clearings in the jungle, is that which produces the camphor; of its abundance it is scarcely necessary to remark, that it is, next to grass, in excess of all other spontaneous vegetable life, and with proper appliances in the manufacture of the salt (its property), might be rendered useful as an article of commerce*."

The probable effects on the climate of Penang, of the continued destruction of the hill jungles of that island, are ably stated by J. S. Logan, Esq., in the same journal (vol. ii. p. 534 *et seq.*). "It was remarked that the whole of the eastern front of the range (in Penang) has within a few years been denuded of its forest; the greater part of it is too steep for any permanent cultivation, and in all probability, after the fecundity of the fresh soil enriched by the ashes of the trees has been exhausted, it will be abandoned by the Chinese squatters. It was not here alone that I was surprised to see the rapid progress which squatters and Chinese charcoal-burners have made in destroying the jungles in the hills during the last two years. In Singapore, the present zealous Governor (Col. Butterworth) has in an enlightened spirit, akin to that which has for some time characterized the Government of India in reference to the same subject, *absolutely prohibited* the further destruction of forests on the summits of hills. Representations have often been made to the local authorities at Penang, urging the necessity of reserving the jungles on the summits and higher slopes, but hitherto without effect. The reply

* Mr. O'Riley, 'Vegetable Productions of Tenasserim.' Provin. Journ. Ind. Archipel. Feb. 1850.

has been, if the forests are of so much importance as the agriculturists insist, they must have a certain value to them, and they are at liberty to purchase any tract they choose. But it is impracticable for the holders of land to unite in making such a purchase; and were it at all practicable, the majority, from ignorance and selfishness, would refuse to contribute. But *climate concerns the whole community*, and its prohibition from injury is one of the duties of Government. In Germany and France there are especial laws for the protection and extension of forests*. It is not necessary to cite Humboldt or Boussingault to prove the great influence in tropical regions of forests, and especially mountain forests, in attracting and condensing clouds, *diminishing local temperature*, and *increasing humidity*. But if the forests had no other effect than to protect the *clay soil* of the mountains from the action of the sun's rays, this ought alone to be sufficient to secure their careful preservation. It is in this soil that the waters which supply all the streams of the island, and which percolate downwards to the lower lands, are enclosed. These mountains are, in fact, great natural reservoirs, elevated in mid-air and exposing the most extended surfaces possible, which are covered to a small depth with a sponge of porous decomposed rock, for the absorption and retention of water. In ordinary seasons, when there is a considerable fall of rain, the importance of preventing the contents of these reservoirs from being dissipated may not be so obvious; but it may now be considered a well-established fact that the Eastern Archipelago is subject to periodical droughts, although the laws of their recurrence are not yet ascertained. That such droughts will again and again happen, and are in fact the settled course of nature, admits of no question.

"Nature, when left to herself, provides a compensatory influence in the dense leafy forests; but if these are consigned to destruction, every successive drought will prove more baneful than the preceding. Unless Government will reserve at least the steeper mountain tracts, which are not adapted for permanent culture, there is nothing visionary in the apprehension, for it has been realized in other localities, that in some prolonged droughts, after the naked sides of the hills have been exposed to the direct heat of the sun, every stream in the inland will be dried up, and universal aridity ensue. The great extent to which the mainland of Penang has been shorn of its forests, would of itself produce an urgent necessity for a stop being at once put to a war with nature, which must entail severe calamities for the future. In those mountains in Greece which have been deprived of their forests, the springs have disappeared. In other parts of the globe the same consequence has followed. The sultry atmosphere and dreadful droughts of the Cape de Verd Islands are owing to the destruction of the forests. *In large districts of India, climate and irrigation have rapidly deteriorated* from a similar cause, and the Government having become fully impressed with the necessity of respecting the stubborn facts of nature, every means have been used to avert and remedy the mischief. Forests which had been so easily and thoughtlessly cut down have at great cost been restored."

We extract the following very interesting results of tree plantations, show-

* They have the same in all the Italian States. So far back as 1475 the subject attracted the attention of the famous Venetian Council of X., by which a law was passed on the 7th of January of that year, regulating in great detail the clearance of the forests on *terra firma*. The mountain forests especially were protected by judicious regulations, which were renewed from time to time down to the very year of the extinction of the old republics. Tuscany and the Pontifical governments were equally provident.—*Idraulica Ragionata di Mengotti*, p. 321 *et seq.*

ing that they may be self-supporting, from an article in the Calcutta Review (No. 23), by Captain R. Baird Smith, Bengal Engineers:—

"The formation of plantations early occupied the attention of the British Superintendents of the Western Jumna Canal. Something was done by Captains Blane and Tickell; but it was left to Colonel Colvin to proceed systematically in this useful duty. An allowance originally of 2000 rupees, afterwards increased to 3000 rupees per annum, was allotted to the plantations, and they have been spread over all parts of the canals to which water could reach. The trees planted are chiefly the Sissú, the Toon, the Kikur, the Cirrus, the Saul, and the Teak, all furnishing wood of value for œconomical purposes. The revenue derived from the plantations, although not large, has more than covered all expenditure upon them; and their ultimate value will be very considerable. The details of the kind, number and estimated present value of the trees on the 30th April 1847, are shown below:—

Kikur (*Vachellia farnesiana*)	91,520
Bambus (*Bambusa*, var. sp.)	4,420
Jamun (*Eugenia Jambos*)	6,914
Kutchna (*Bauhinia*)	1,771
Mangos (*Mangifera indica*)	1,060
Mulberry (*Morus*, var. sp.)	18,746
Nim (*Melia Azaderach*)	7,126
Cirrus (*Acacia Serissa*)	13,966
Sissú (*Dalbergia Sissoo*)	1,84,252
Toon (*Cedrela toona*)	35,487
Sundry	9,990
Total	3,75,252

"The estimated value of these trees is 5,66,998 5 4 rupees, and the total expenditure by Government up to the present time amounts to only 27,363 5 7 rupees, or about one-fourth of the revenue derived from the plantations, as shown in the annexed statement:—

"*Statement of Revenue from Sale of Wood, Grass, &c. from the Plantations of the Western Jumna Canals*:—

	Rupees				Rupees		
1820–21	635	11	0	1835–36	4,957	11	9
1821–22	1180	9	4	1836–37	2,245	6	0
1822–23	741	7	11	1837–38	5,221	8	8
1823–24	656	0	10	1838–39	6,171	4	2
1824–25	545	7	7	1839–40	4,822	14	10
1825–26	370	9	9	1840–41	5,481	6	0
1826–27	713	13	11	1841–42	5,607	3	7
1827–28	1460	13	9	1842–43	6,756	12	2
1828–29	1289	8	8	1843–44	4,827	5	3
1829–30	1142	15	4	1844–45	5,149	11	1
1830–31	1265	4	8	1845–46	7,056	0	1
1831–32	2127	7	0	1846–47	10,167	10	4
1832–33	2651	2	11				
1833–34	3894	6	11	Grand total	90,822	6	4
1834–35	3,682	2	10				

"The plantations on the Eastern Jumna Canal were commenced simul-

taneously with the canal itself, and have been extended systematically from that period up to the present time. The kinds and numbers of the trees in the canal plantations are shown below:—

Sissú	209,870	Lullow	2,774
Cirrus	8,058	Teak	1,158
Kikur	28,501	Toon	15,967
Nim	6,799	Sundry	7,416
Mulberry	9,305		
Bambus	1,906	Total	291,754

"The estimated value of the plantations is 1,46,793 rupees; and the total expense incurred by Government in their formation up to April 1847, is 22,142 1 2 rupees, which sum, as will be seen by the following statement, has been nearly covered by the sale of wood, &c. from the banks.

"*Statement of Annual Revenue from Sale of Plantation Produce on the Eastern Jumna Canal*:—

	Rupees.				Rupees.		
1830–31	592	15	3	1840–41	2,470	0	5
1831–32	606	6	2	1841–42	1,645	3	5
1832–33	665	7	7½	1842–43	1,940	7	6
1833–34	773	11	8	1843–44	1,413	12	9
1834–35	815	15	5¼	1844–45	1,704	1	11
1835–36	1,034	9	4	1845–46	1,725	11	1
1836–37	1,168	5	2	1846–47	1,842	0	11
1837–38	1,222	5	2				
1838–39	1,073	9	1	Grand total	21,977	2	10¾
1839–40	1,282	8	0				

"In addition to the plantations of forest-trees, grafted mango gardens have lately been established with the view of introducing a superior fruit into the country adjoining the canal. Of these gardens five are in existence, containing about 300 trees each, and being from three to five acres in extent; the result of their establishment has been very satisfactory; and although only one of the number has yet arrived at maturity, they have proved very successful, the demand for grafts and fruit being much in excess of the means of supply. The native community, for whom they were chiefly intended, have shown their appreciation of them by purchasing a large number of grafts, and there is every probability that the intention of Government in sanctioning the project will be fully realized."

The following observations on the spread of tree-cultivation throughout the north-western provinces, are from the Proceedings of the Agricultural and Horticultural Society of India, April 1841:—

"The Hon. the president (Sir Edward Ryan) called attention to a subject which engaged much the consideration of parties interested in furthering the agricultural welfare in the provinces of Upper India. He alluded to the great want which was felt for a sufficiency of timber-trees and firewood throughout the Azimghur, Jaunpore, part of the Benares, the Dooab, Rohilcund, and Delhi provinces, now that the manufacturing energies of the people were becoming aroused by the increasing demand that there was for sugar. This Society (he stated) had a gold medal placed at its disposal by Mr. Tucker, for presentation to any individual who might raise the largest plantation of trees in the Agra presidency, so impressed was this gentleman of the necessity of some steps being taken to promote so important a measure.

" In recommending more general attention to the subject of planting in India, it is perhaps unnecessary, after detailing the foregoing facts, to dwell longer on what appears to be the absolute necessity of something being done either by Government or by individuals for the preservation of old forests or the formation of new ones, whether this be immediately profitable or not, because so long a time is required to bring timber to perfection, that unless some means are adopted to provide for the future, so great a dearth of timber will be experienced as to put a stop to constructions of all kinds, that is to almost everything required for civilized life, or to force the Government and natives of India to import timber at any sacrifice, even when there are abundant tracts of unprofitable land, which might have been occupied by valuable timber, and which would have yielded yearly some returns long before the trees were fit to cut down. In India, not only would the thinnings and prunings of forests be required for all the purposes for which these are sold in Europe, but a constant demand and profitable sale must always give value to even the smallest fragments of wood in a country where it is the universal fuel for daily cooking the food of millions, as well as for imparting warmth in the cold-weather months, and required also for all the chemical arts in which heat is necessary, some of which, as the preparation of sugar and of indigo, are performed on the very farms where the plants are grown. The leaves also of many trees are employed as fodder for elephants, camels, and in the Himalayas even for goats, sheep, and horned cattle. They are collected also when dry for fuel, and are preferred, I believe, for some fires, as those for heating ovens; but their more legitimate employment, of being allowed to enrich the soil, becomes neglected."—*Royle, MSS. cit.*

" Another object I would particularly call attention to, is the felling of timber at the proper season when the sap is at rest. It requires no botanist to point out when this is to be done; although the leaves do not fall off in India, as in more temperate climates, it is impossible to find any difficulty in deciding, from the appearance of the tree, when the time for felling has arrived. When the sap is rising, the leaves are generally somewhat soft and perfect; when it is at rest, the leaves are harder, and, in India, almost always corroded by insects. In consequence of the facility of barking a tree when the sap is rising, oaks are often felled at this season in England, always with disadvantage to the timber; and this same facility of barking is too often an inducement to the renters of forests in India to fell timber at improper periods of the year."—(Capt. Munro on the Timber Trees of Bengal, in Asiatic Society of Bengal, No. XI. new series, page 1.)

It is not only in affording indigenous woods of wonderful variety, serving all the purposes to which timber is applied, that the Indian forests claim our attentive consideration. In them Nature presents to us other sources of wealth, which under judicious management may yield a considerable increase to the present revenue. Gums, drugs, dyes, resins abound, as gutta-percha, caoutchouc, kino, gamboge, camphor, dammer, piney, varnish, wood-oil, with many other products not sufficiently known or appreciated, but which, as the light of European science penetrates these partially explored regions, will be applied to many useful purposes in the arts and sciences.

The *Isonandra gutta* flourished for centuries in its native jungles, exuding its juice only to be received by the soil, before the discovery was made that gutta-percha was suited for such an infinite number of applications (the properties of the other species remain to be examined), and the geographical limits of the *Taban*-tree have yet to be ascertained. To urge the necessity of exercising careful vigilance in protecting the trees whence so valuable a

product is derived, will perhaps appear unnecessary, but we know that even their admitted financial value has not been sufficient to protect them from thoughtless waste, but the contrary, as has been illustrated by various writers in the Journal of the Indian Archipelago.

The recent discovery of the source of East Indian Kino by Dr. Royle*, the researches of Dr. Christison as to the new varieties of gamboge, and the various investigations of Dr. Pereira, are instances of interesting and important advances in the medical botany of the Indian forests. The abundance of *Pterocarpus marsupium* over the continent of India, producing the kino, and the occurrence of *Garcinia pictoria* and *elliptica*, yielding the gamboge, both in Coorg and Burmah, lead to the conclusion that much remains to be done in developing the pharmaceutic resources of these forests.

We are assured by the Rev. Mr. Mason†, Mr. O'Riley‡, and other observers, that the gamboge-trees (*Garcinia elliptica*) are dispersed through the forests of Burmah in such numbers as to afford a considerable quantity of the exudation, did the knowledge of its value and the process of preparing it exist with the natives (Kareans). The tree however is felled indiscriminately with the rest of the forest in the annual clearings which take place, and the article, which forms a prominent item in the rich exports from Siam, is on the eastern side of the border range utterly neglected and destroyed.

"The districts where the Burmese gamboge is produced are nearly in the same latitude with Cambodia, where the commercial gamboge of Siam is known to be collected; the two localities are even at no great geographical distance from each other, and hence a strong presumption arises that the tree of Burmah is the same with the unknown gamboge-tree of Siam§."

The Coorg or Wynaad gamboge-tree has an extensive range; we have seen it along all the higher parts of the Malabar Ghauts for fully 120 miles from north to south, and in some parts it is very abundant; yet the produce for the most part is made little use of, and the tree is considered of so small value, that we have seen the supports and scaffolding of bridges, &c. entirely composed of the stems of *Garcinia pictoria*, though from the valuable observations of Dr. Christison, this gamboge may be advantageously applied to any use to which the gamboge of Siam is habitually put. We are glad to learn that it is now becoming much used as a pigment||; and as the exudation may be obtained in large quantity, it may be introduced equally to European trade, when once the natives learn how to collect it in a state of purity, and make it up in homogeneous masses, in imitation of pipe gamboge, the finest Siam variety.

The names of the trees producing gamboge and kino should be added to the list of trees protected from indiscriminate destruction, which list, so far as we know, is at present limited to the Teak, Ebony, Black-wood and Sandalwood.

Many other trees should no doubt be added to this list. In the present state of our knowledge, however, we shall not venture to refer to any, except the oil-yielding trees, of which the commercial importance cannot be over-

* Pharmaceutical Journal, May 1846, p. 500.

† Journal of the Asiatic Society of Bengal. ‡ Journal of Indian Archipelago.

§ Christison, in Pharmaceutical Journal for August 1846.

|| In illustration of the variety of indigenous pigments, we may state that one of our number (Dr. Cleghorn), finding his colour-box becoming exhausted, was enabled to supply all his deficiencies, without difficulty, from the natural products of the surrounding forest, including yellow from *Garcinia pictoria*, blue from various species of *Indigofera*, red and purple from *Oldenlandia umbellata*, "Pupplay Chukkay" (*Ventilago*?) and *Vatica laccifera*.

rated, and to which comparatively little attention has yet been paid. In the limits of a report like the present, we can only indicate in a cursory manner the names of the more important and best known trees of this class. We may especially allude to the different species of Bassia, *Stillingia sebifera* (tallow-tree of China), *Vateria Indica*, which, from the high melting-point of their oils or fats, have a peculiar importance from their use in the manufacture of candles, and from their being capable of replacing animal fats for other purposes. Of those trees which yield fluid oils, *Calophyllum inophyllum*, *Aleurites triloba*, and *Pongamia glabra*, may be particularly mentioned (though various others possessed of equally valuable properties would probably be discovered by a more careful examination of those forests). The demand for oils in European commerce has been steadily on the increase for some years past, and the quantities consumed are now so large that these and the other oleaginous products of tropical climates must sooner or later acquire considerable commercial importance, and render the preservation of the plants which yield them deserving the attention of Government, not so much from their present importance, as from the value which they are likely soon to acquire.

We have alluded to gutta-percha; its brief but remarkable history was lately detailed in an overland journal. The history of *gutta-percha* or *gutta-taban*, is brief but not uneventful. Previously to 1844 the very name of gutta-percha was unknown to European commerce. In that year two cwts. of it were shipped experimentally from Singapore. The exportation of gutta-percha from that port rose in 1845 to 169 piculs (the picul is $133\frac{1}{3}$ lbs.), in 1846 to 1364, in 1847 to 9296, in the first seven months of 1848 to 6768 piculs. In the first four and a half years of the trade 21,598 piculs of gutta-percha, valued at 274,190 dollars, were shipped at Singapore, the whole of which was sent to England, with the exception of 15 piculs to Mauritius, 470 to the Continent of Europe, and 922 to the United States.

But this rapid growth of the new trade conveys only a faint idea of the commotion it created among the native inhabitants of the Indian Archipelago. The jungles of Johore were the scene of the earliest gatherings, and they were soon ransacked in every direction by parties of Malays and Chinese, while the indigenous population gave themselves up to the search with unanimity and zeal. The Tamungong, with the usual policy of Oriental governors, declared the precious gum a government monopoly. He appropriated the greater part of the profits, and still left the Malays enough to stimulate them to pursue the quest, and to gain from 100 to 400 per cent. for themselves on what they procured from the aborigines. The Tamungong, not satisfied with buying at his own price all that was collected by private enterprise, sent out numerous parties of from 10 to 100 persons, and employed whole tribes of hereditary serfs in the quest of gutta-percha.

This organized body of gum-hunters spread itself like a cloud of locusts over the whole of Johore, peninsular and insular. They crossed the frontier into Linga, but there the Sultan was not long in discovering the new value that had been conferred upon his jungles. He confiscated the greater part of what had been collected by the interlopers, and in emulation of the Tamungong, declared *gutta-percha* or *gutta-taban* a royalty. The knowledge of the article, stirring the avidity of gatherers, gradually spread from Singapore northward as far as Penang, southward along the east coast of Sumatra, to Java, eastward to Borneo, where it was found at Brune, Sarawak and Potianak on the west coast, at Keti and Passir on the east. The imports of gutta-percha into Singapore from the 1st of January to the 12th of July 1848, according to their geographical distribution, were from the Malay

peninsula 598 piculs, from the Johore Archipelago 1269, from Sumatra 1066, from Batavia 19, from Borneo 55. The price at Singapore was originally 8 dollars per picul; it rose to 24, and fell about the middle of 1848 to 13. In the course of $3\frac{1}{2}$ years 270,000 taban-trees were felled in order to get at the gum, and nothing has been done to replace them.—*Express*.

We cannot help adverting in this place to the superb series of Indian timbers in the Exhibition, and also the very extensive collections of woods in the East India House; the former contain large contributions from the Northern Circars, Coimbatore, Assam, Arrackan and Malabar. The East Indian Museum contains a collection of 117 specimens sent by Dr. Roxburgh, 100 from Java by Dr. Horsfield, and 456 from Dr. Wallich, who gave the duplicates of his collection to the Society of Arts, of which they published a list in their Transactions, vol. xlviii. p. 439, and for which they awarded the gold Isis medal. These sufficiently illustrate the great variety and great importance of the timber-trees of India, of which the following are the kinds chiefly used. Much useful information will be found in Holtzappfel's Descriptive Catalogue of Woods used in Turnery, to which notes have been added by Dr. Royle*.

Timber-Trees of India.

Botanical Names.	Natural Orders.
Tectona grandis, Teak	Verbenaceæ.
Gmelina arborea	"
Hemigymnia Macleodii	"
Vitex arborea	"
Premna hircina	"
——— flavescens	"
Cedrus Deodara	Pinaceæ.
Cupressus torulosa	"
Diospyros Melanoxylon	Ebenaceæ.
Pterocarpus marsupium, Kino-tree	Fabaceæ.
——— santalinus	"
Dalbergia Sissoo	"
——— latifolia, Blackwood	"
Acacia arabica, Babool	"
——— catechu	"
——— speciosa	"
——— sundra	"
——— Serissa	"
Vachellia farnesiana	"
Vatica robusta	Dipterocarpaceæ.
Calophyllum, Poon	Garciniaceæ.
Heritiera minor	Sterculiaceæ.
Tamarix	Tamaricaceæ.
Rhododendron arboreum	Ericaceæ.
Nauclea cordifolia	Cinchonaceæ.
Hymenodictyon excelsum	"
Buxus emarginatus, Box	Euphorbiaceæ.
Grewia elastica	Tiliaceæ.
Berrya ammonilla	"
Quercus dilatata	Quercaceæ.

* I have here to express regret that my approaching departure for India prevents me from giving so complete a list as I could wish, and entering at length upon details regarding the œconomic uses of some to which I paid considerable attention in India.

Botanical Names.	Natural Orders.
Cedrela Toona	Cedrelaceæ.
Chloroxylon Swietenia, Satin-wood	„
Santalum album, Sandal-wood	„
Swietenia Mahogani, Mahogany	„
Soymida febrifuga	„
Chickrussia tabularis	„
Lagerströmia	Lythraceæ.
Terminalia tomentosa	Combretaceæ.
——— Belerica	„
——— Catappa	„
Conocarpus latifolia	„
Artocarpus integrifolia, Jack	Artocarpaceæ.

The general conclusions which appear to the Committee to be warranted, by the various statements of fact and opinion as given in their Report, are summed up as follows:—

1. That over large portions of the Indian Empire, there is at present an almost uncontrolled destruction of the indigenous forests in progress, from the careless habits of the native population.

2. That in Malabar, Tenasserim, and Scinde, where supervision is exercised, considerable improvement has already taken place.

3. That these improvements may be extended by a rigid enforcement of the present regulations and the enactment of additional provisions of the following character; viz. careful maintenance of the forests by the plantation of seedlings in place of mature trees removed, nurseries being established in the immediate neighbourhood,—prohibition of cutting until trees are well-grown with rare and special exceptions for peculiar purposes. In cases of trees yielding gums, resins, or other valuable products, that greater care be taken in tapping or notching the trees, most serious damage at present resulting from neglect in this operation.

4. That especial attention should be given to the preservation and maintenance of the forests occupying tracts unsuited for culture, whether by reason of altitude or peculiarities of physical structure.

5. That in a country to which the maintenance of its water supplies is of such extreme importance, the indiscriminate clearance of forests around the localities whence those supplies are derived is greatly to be deprecated.

6. That as much local ignorance prevails as to the number and nature of valuable forest products, measures should be taken to supply, through the officers in charge, information calculated to diminish such ignorance.

7. That as much information which may be of practical utility is contained in the Manuscript Reports and Proceedings of the late "Plantation Committee," it is desirable that the same should, if practicable, be abstracted and given to the public.

To show the sources whence the information has been derived, the Committee annex the following statement of authorities:—

I. On the general question of Indian Forests:—

Dr. Roxburgh: In Flora Indica, on properties of different Timber Trees of India.

Dr. Wallich: Reports connected with Natural Forests of the Empire, and Proceedings of Agri-Horticultural Society of India.

Dr. Royle: Productive Resources of India. *Passim.*

MS. Report on Plantations.

On the Sources of East India Kino. *Pharmaceutical Journ.* April, 1846.
Capt. Munro: Timber Trees of Bengal. *Journ. As. Soc. Beng.*
Dr. E. G. Balfour: Effects of Trees on Climate and Productiveness. *Madras Journ. Sc.*

II. Forests of Malabar and Canara.

Dr. Gibson: Various Reports on the above.
Dr. A. Turnbull Christie: *Jameson's New Philosophical Journal.*
Mr. J. Edye: Malabar Forests. *Journ. As. Soc.* II.
Capt. Threshie: On the Timber of Malabar, MS.
Dr. D. Macfarlane: Private Correspondence.

III. Travancore.

General Cullen: On the Influence of Forests on Climate. *Madras Journ. Sc.*, 1850.

IV. Mysore.

Dr. Buchanan Hamilton: Journey through Mysore. 1801. *Passim.*
Dr. Christison: On Gamboge, a Vegetable product of the Mysore Forests. *Pharm. Journ.*, Aug. 1846.
Capt. Onslow: Report on Forests of Nuggur, MS.
C. J. Smith, Esq.: On Effects of Trees on Climate. *Madras Journ. Sc.*, 1850.
Dr. H. Cleghorn: Hedge Plants of India. *Ann. Nat. Hist.*, 2nd series, vol. vi. Also MSS.

V. Coimbatore and Neilgherries.

Dr. Wight: Private Correspondence and Neilgherry Plants.

VI. Tenasserim.

Dr. Wallich: Various MSS. very valuable.
Dr. Helfer: Reports on Tenasserim Provinces. *Journ. Asiat. Soc., Bengal.*
Mr. Blundell: Reports, MS.
Mr. Seppings: Reports, MS.
Mr. O'Riley: Vegetable Productions of Tenasserim. *Prov. Journ. Ind. Archipel.*, Feb. 1850.
Col. Tremenheere: Reports on Teak Forests, MS.

VII. Penang and Singapore.

J. S. Logan, Esq.: Climatic Effects of Destruction of Forests in Penang. *Journ. Ind. Archipel.* vol. ii. p. 534.

VIII. North-Western Provinces.

Dr. J. Forbes Royle: Illustrations of Himalayan Botany.
Colonel Cautley: Report on Forests of Dejrah Dhoon, MS.
Mr. Tucker: Proceedings of Agric. Soc. of India.
Captain Baird Smith: Agricultural Resources of the Punjaub. Canals of Irrigation in the N.W. Provinces (Plantations). *Calcut. Review*, No. ix.
Captain R. Strachey: Journ. Asiat. Soc., Bengal.
Dr. Joseph D. Hooker: Notes of Excursion from Darjeeling to Sikkim in Journ. Asiat., Bengal.

APPENDIX.

In 1847 the Court of Directors sent a despatch to the Supreme Government, requesting the attention of the authorities to the effect of trees on the climate and productiveness of a country or district. On receiving this communication, the Madras Government directed a circular to their revenue officers requesting them to forward any of the required information in their power, and several valuable reports were accordingly received in reply, some of which we annex as follows :—

General Cullen, Resident of Travancore :—"There cannot perhaps be a more beautiful illustration of the effect of mountain chains in arresting and condensing the vapour, than the generally luxuriant forests which clothe the eastern as well as the western ghauts, but which cease almost immediately on quitting those chains. The forests on the east coast, as might be expected, are less lofty and luxuriant than those in Malabar, not only from the fall of rain on the east coast being only half that of Malabar, but also because they are in general double the distance from the sea, the chief source of all vapour.

"There can of course be little question as to the effect forests must have during a great part of the year, in preventing the dissipation of the superficial moisture, but I should doubt if that circumstance can have much influence on the supply of water from springs. The effect of the sun's rays on the earth, even when fully exposed to them, is sensible to but a very inconsiderable depth from the surface, and not at all so far as the subsidence of the water forming springs. The copiousness of springs must be influenced so much by a variety of other causes as to render the effect of forests hardly appreciable. The vicinity to elevated table-lands and mountains and hills, the nature of the rocks, and inclination of the strata, the general slope of the country, the absorbent qualities of the soil, &c., must all have the most important influence. At Trevandrum, even on eminences, the wells at a depth of forty feet from the surface rise occasionally several feet with a fall of rain of only the same number of inches, and within two or three days after heavy falls.

"In the forests of this coast, and above the ghauts in the western parts of Mysore, Wynaad and Coorg, the trees are, I believe, everywhere nearly destitute of leaves during the early part of the year, the driest and the hottest season; so that even in forest tracts the earth is at that period exposed to nearly the full force of the sun's rays.

"The long grass and low jungle are also generally burnt down in these months, and the general heat and dryness in passing through such tracts are frequently intolerable. The almost entire absence of moisture and springs in forest tracts in the dry season is well known.

"The district of Ernaad in Malabar, formerly so celebrated for its teak forests, and still, I believe, with much forest of other kinds, is, I believe, for the most part a plain and nearly level, but in the hot season is like the other tracts I have noticed, equally destitute of vegetation and moisture, and I speak of these facts from having, although many years ago, passed over all the tracts in question."

Surgeon C. J. Smith, Bangalore :—"In the Mulnaad and Coorg the quantity of rain that falls is very great; and to what can we attribute this, but to the influence of the ghauts and hilly country inland, covered with dense jungles, which attract and retain the largest portion of the south-west monsoon? Bellary, Seringapatam, and Octacamund are nearly in the same parallel of longitude, but at different distances from the line of ghauts, and to

this circumstance we may attribute the difference in the falls of rain at these stations."

Assistant-surgeon Balfour, in his notes on this subject, has well remarked, 'that the observations of scientific men support the belief that a mutual re-action goes on between these two physical agents, and that the presence of trees greatly adds to the supply of water and feeds the running streams.' The instance of a single district losing its supply of water on being cleared of forest, and regaining it again when restored to its original state, would not alone establish more than strong presumption that the clearing of the forest and the loss of rain followed each other as cause and effect; but the Honourable Court of Directors, in their circular, mention that this is not uncommon in America.

On the subject of springs, Assistant-surgeon Balfour quotes from Jameson's Edinburgh Philosophical Journal, a very remarkable instance at Popayan in Peru, of a district losing its supply of water from the clearance of the forest:—"Two instances corroborative of the above have come under my own observation, and happened to friends in different parts of the country engaged in coffee-planting. The first happened in a range of hills south-east of Bangalore, at a coffee plantation now called Glenmore, in the Debenaicottah talook of the Salem district. The proprietor, when preparing ground for a coffee garden which was watered by an excellent spring, was warned by the natives not to clear away the trees in the immediate neighbourhood of his spring; he disregarded their warning, cut down the trees, and lost his stream of water. The other instance happened at the village of Hoolhully, about eight miles distant from the head of the new ghaut in Mungerabad; I wrote to the gentleman to whom it occurred, who answered as follows:—'The cutting down trees and clearing jungle on the sides of ravines in the close vicinity of springs, undoubtedly has a great effect in diminishing the quantity of water. I found it so in one or two instances in ravines I had cleared for planting; at one place where I had a nursery, which I used to water by turning a water-course from the spring, I found that since I cleared up the sides of the ravine in which the spring is (for planting), I have not anything like the quantity of water I had before the shade was cleared. I presume this is to be accounted for by the increased action of the air and sun; at any rate the natives about here are of that opinion. I leave the cause, however, to be settled by more scientific men than myself; that the effect is so, there is no doubt. A ravine close to the bungalo where there is a spring, a few years ago I cleared for planting, and found the water decrease in like manner; but the coffee-trees dying away, and the place being too small for a plantation, I did not renew them, but allowed the jungle to grow up again, since which the stream has nearly regained its former size.'"

The superintendent of Nuggur writes, "that springs of water shaded by trees, almost invariably dry up on the trees being cleared away. This has been observed on the Neilgherry Hills and many other woody districts." In what way trees influence springs it is impossible to say; that they do so seems to be established, as also that they condense and attract vapour.

"This effect of trees in mitigating the intensity of tropical heat, has also been alluded to by the present superintendent of forests in our western presidency, who mentions that in the southern districts of Guzerat the vicinity of the sea and the proximity of the mountain tracts covered with jungle, tend to render the climate more mild, and the temperature throughout the year more equable than is the case in the other parts of the province. Further inland, and in the immediate vicinity of the hills, the heat is greater, and in both situations the humid and loaded atmosphere in the S.W. monsoon is often pain-

fully felt, particularly at night. In the whole of this district rain falls in greater quantities than to the northward; in the jungle districts to the east, the supply of rain is said never to fail in the driest of seasons, and it often falls there when none is apparent in the more open districts.

"It is in such tracts as these that rivers rise, for from the number, height, and comparative proximity of the hills to the southward of the Taptee, we might, *à priori*, suppose that the supply of water in that district would be abundant: and such is actually the case, as we find in a breadth of fifty miles eight rivers, all containing water throughout the year. Reasoning from these facts, we may also predicate the sort of country in which these rivers have their origin, viz. underlying hilly tracts abounding in rich soil, highly retentive of moisture, and rendered still more so by luxuriant jungle."—*Surgeon Gibson in Tr. Bomb. Med. and Phys. Soc. Journ.*, pp. 37, 41.

Report from Dr. Gibson, dated 9th March 1846.—"In the collectorate comprising the South Conkan, under Bombay, since this tract has been denuded of forest, as it now has been to a great extent from the pressure of population, all the inhabitants concur in asserting that the springs have left the uplands, that the climate has become greatly drier, the seasons more uncertain, and the land less fertile. I believe that this can be confirmed by the testimony of the late collector Mr. Elphinstone, but indeed it is most apparent to a person travelling along that line of country, as I have just now been doing, mainly with the intention of remarking changes which have taken place in the interval of fifteen years, which period of time has elapsed since I visited that line of country before; I have also understood that effects of a similar kind have been experienced at the Neilgherry Hills. A change of climate, similar to that now under contemplation, is by no means limited in extent to the mere district in which the clearing has taken place, but its influence extends far inland. Take for example all the southern and western portion of the Dharwar Zillah. This fertile country abounds in moisture, insomuch that it has been (though rather inaptly, I think) compared to the valley of the Mississippi; at all events American upland cotton grows there, which it will hardly do in other parts of the Bombay presidency. I think it is not too much to say, that much of this moisture depends on the wooded country forming its western border, and that with the complete removal of this, the climate would greatly change. My own opinion is, that in the Bombay presidency some cause of this kind has had a great share in producing that irregularity of the rainy season which has of late years been so much complained of, as to diminished fertility of the soil from the removal of belts of wooded country; the rationale of this is most evident."

On the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants. By ARTHUR HENFREY, *F.L.S.*

HAVING been prevented by the pressure of other engagements from complying with the request which the Association did me the honour to make last year, that I should assist Prof. Lindley and Dr. Lankester in preparing a Report on Vegetable Physiology, I venture to present a fragmentary contribution on the subject, relating to a branch of the science to which my attention has been recently strongly attracted, in the pursuit of my own investigations. I was the more induced to devote the short time at my disposal to

drawing up a summary of the state of knowledge of the reproduction of the higher flowerless plants, by the importance of the discoveries which have recently been made in this department, tending completely to change the general views which have hitherto been entertained by most botanists as to the extent to which sexuality exists in the vegetable kingdom, and in connexion with other new facts relating to the Thallophytes, to indicate that the existence of two sexes is universal.

Under the name of the higher Flowerless Plants, I include all those classes which are distinguished on the one hand from the Thallophytes or Cellular plants by the presence of a distinct stem bearing leaves, and on the other from the Monocotyledons and Dicotyledons by the absence of the organs constituting a true flower; they are, the Hepaticæ, Musci, Equisetaceæ, Filices, Lycopodiaceæ, Isoëtaceæ, and Marsileaceæ or Rhizocarpeæ.

On no subject has more discussion been maintained than on the existence of sexes among the Cryptogamous families. The discovery of the two kinds of organs, the *antheridia* and *pistillidia*, in the Mosses and Hepaticæ, and of the peculiar organs containing analogous spiral filaments in the Characeæ, were for a long time the chief facts brought forward by those who supported the sexual hypothesis; and in the endeavour to carry out the view into the other tribes, a similar nature to that of the *antheridia* was attributed to most varied structures in the Ferns and other plants. These attempts to find distinct sexual organs were in some instances pursued with so little judgement, that the opinion had of late years fallen in some degree into discredit, and two circumstances contributed still further to strengthen the doubts which were entertained. The first was the exact analogy, pointed out by Prof. von Mohl, between the mode of development of the spores of the Cryptogamia and the pollen-grains of the flowering plants, which interfered very importantly to prevent any comparison between the sporangia and ovaries, and apparently determined the analogy of the former to be with anthers. The second was the discovery by Prof. Nägeli, of organs producing spiral filaments, therefore analogous to the *antheridia* of the Mosses, on the germ frond, or *pro-embryo* developed from the spores of the Ferns.

At the same time, the facts observed in *Pilularia* were altogether equivocal. Mr. Valentine* traced the development of the larger spores, exhibiting in germination an evident analogy to ovules, from cells closely resembling the parent-cells of pollen and spores; while Prof. Schleiden stated that he had observed a fertilization of these supposed ovules by the smaller spores resembling pollen-grains, and thus seemed to remove the ground for attributing a fertilizing influence to the spiral filaments contained in the so-called *antheridia* of the Cryptogams.

In this state the question remained until 1848, when Count Suminski † published his observations on the germination of Ferns, showing that the researches of Nägeli had been imperfect, and that two kinds of organs are produced upon the pro-embryo of the Ferns, one kind analogous to the *antheridia*, and the other to the *pistillidia* of Mosses; from the latter of which the true Fern stem is produced, like the seta and capsule from the same organ in the Mosses; further stating that he had actually observed a process of fertilization. Soon after this M. G. Thuret‡ discovered *antheridia* like those of the Ferns in the Equisetaceæ; Nägeli § had previously

* Linnean Transactions, vol. xvii.
† Entwickelungsgeschichte der Farrenkräuter. Berlin, 1848.
‡ Ann. des Sci. Nat. ser. 3, vol. xi. 1849.
§ Zeitschrift für Wiss. Botanik, Heft 3. Zurich, 1846.

published, in opposition to Schleiden's observations, an account of the production of spiral filaments from the small spores of *Pilularia*, and finally M. Mettenius* discovered them in the small spores of *Isoëtes*. Thus they were shown to exist in all the families above enumerated, with the exception of the Lycopodiaceæ, in which they have recently been stated to exist by M. Hofmeister†. Before entering into a detailed account of their discoveries, it may be mentioned, that, besides their well-known occurrence in the Characeæ, which most authors consider as Thallophytes, antheridia are stated by Nägeli to exist on the Florideæ, among the Algæ; and peculiar bodies to which the same nature has been attributed, were recently discovered by M. Itzigsohn in the Lichens; a discovery confirmed by Messrs. Tulasne, who state that analogous bodies exist in many Fungi. Our knowledge of these latter points is, however, far less definite than that concerning the higher tribes, and I shall not include them in the following summary.

One of the most remarkable circumstances concerning the antheridia of the leaf-bearing Cryptogams, is the very varied nature of the time and place of their development; so great indeed is this, that it is only their essential structure, and the production of the moving spiral filaments in particular, which warrants the assumption of their identity of function in the different families. In order to make these variations clearly comprehensible, it will be necessary to describe the characters exhibited in the germination of the spores in each tribe, as it is only by this means that the important peculiarities of each case can be made evident. It will be most convenient to give a separate sketch of all that is known of the process of reproduction in each family, taking these separately and in succession; after this we shall be in a position to compare them together, and trace out their differences and analogies; the advantage of recalling all the essential facts to memory will, I trust, serve as an apology for the introduction of much that is already familiar to most botanists.

Mosses.—The antheridia of the Mosses occur in the axils of the leaves or collected into a head, enclosed by numerous variously modified leaves, at the summit of the stem. They are produced either on the same heads as the pistillidia, or in distinct heads on the same individuals, such Mossesbeing called monœcious; or the heads are found only on distinct individuals, such Mosses being termed diœcious. The structure of the antheridium is exceedingly simple; it consists of an elongate, cylindrical or club-shaped sac, the walls of which are composed of a single layer of cells, united to form a delicate membrane. Within this sac are developed vast numbers of minute cellules, completely filling it, and, the sac bursting at its apex at a certain period, these vesicles are extruded. When the nearly perfect sacs are placed in water, the vesicles within appear to absorb water, and swell so as to burst the sac of the antheridium, and often adhering together, they collectively appear to form masses larger than the cavity from which they have emerged. Through the transparent walls may be seen a delicate filament with a thickened extremity, coiled up in the interior of each vesicle. Often before the extrusion, but always shortly after, a movement of this filament is to be observed when the object is viewed in water under the microscope. The filament is seen to be wheeling round and round rapidly within the cellule, the motion being rendered very evident by the distinctness of the thickened extremity of the filament, which appears to be coursing round the walls of the cellule in a circle. According to Unger, this filament breaks

* Beiträge zur Botanik, Heft 1. Heidelberg, 1850.

† Flora, 1850, p. 700.

out of its parent cellule in Sphagnum, and then appears as a spiral filament moving freely in water, in fact, as one of the so-called spermatozoa.

The pistillidia of the Mosses are the rudiments of the fruit or capsules. When young, they appear as flask-shaped bodies with long necks, composed of a simple cellular membrane. The long neck presents an open canal like a style, leading to the enlarged cavity below, at the base of which, according to Mr. Valentine*, is found a single cell projecting free into the open space. This single cell is the germ of the future capsule; at a certain period it becomes divided into two by a horizontal partition, the upper one of these two again divides, and so on until the single cell is developed into a cellular filament, the young seta; the upper cells are subsequently developed into the urn and its appendages, and as this rises, it carries away with it, as the calyptra, the original membrane of the pistillidium, which separates by a circumscissile fissure from the lower part, the future vaginula. These observations of Valentine are not exactly borne out by those of Schimper† in some of the detail points. According to this author, the lower part of the pistillidium (the germen of Dr. Brown) begins to swell at a certain time, when a capsule is to be produced, becoming filled with a quantity of what he terms "green granulations." As soon as the thickness has become about that of the future seta, the cell-development in the horizontal direction ceases, and its activity is directed chiefly to the upper part, which begins to elongate rapidly in the direction of the main axis. This elongation causes a sudden tearing off at the base, or a little above it, of the cell-membrane enveloping the young fruit, and the upper part is carried onwards as the calyptra; the lower part, when any is left, remains as a little tubular process surrounding the seta. While the young fruit is being raised up by the growth of the seta, the portion of the receptacle upon which the pistillidium is borne, becomes developed into a kind of collar, and at length into a sheath (the vaginula) surrounding the base of the seta which is articulated into it there.

M. Hofmeister‡, again, describes the details much in the same way as Mr. Valentine. He states that there exists at the point where the 'style' and 'germen' of the pistillidium join, a cell, developed before the canal of the style has become opened. In those pistillidia which produce capsules this cell begins at a certain period to exhibit very active increase; it becomes rapidly divided and subdivided by alternately directed oblique partitions into a somewhat spindle-shaped body formed of a row of large cells. Meanwhile the cells at the base of the germen are also rapidly multiplied, and the lower part of the pistillidium is greatly increased in size. The spindle-shaped body continues to increase in length by the subdivision of its uppermost cell by oblique transverse walls, and the opposition which is offered by the upper concave surface of the cavity of the germen, causes the lower conical extremity of the spindle-shaped body to penetrate into the mass of cellular tissue at the base of the germen, a process which resembles the penetration of the embryo into the endosperm in the embryo-sac of certain flowering plants. The base of the spindle-shaped body, which is in fact the rudiment of the fruit, at length reaches the base of the pistillidium, and penetrates even some distance into the tissue of the stem upon which this is seated. The growth of the upper part going on unceasingly, the walls of the germen are torn by a circular fissure and the upper half is carried upwards,

* Linnean Transactions, vol. xvii.

† Recherches Anatomiques et Morphologiques sur les Mousses. Strasbourg, 1848.

‡ Botanische Zeitung, 1849, 798. Botanical Gazette, vol. ii. p. 70.

bearing the calyptra, the lower part forms the vaginule. The upper cell of the spindle-shaped body then becomes developed into the capsule, and the calyptra often becoming organically connected with this, as the base of the seta does with the end of the stem, it in such cases undergoes further development during the time it is being carried upwards by the growing fruit.

The view now entertained by Schimper, Hofmeister, and others of the reproduction of the Mosses is, that the antheridia are truly male organs, and that they exert, by means of the spiral filaments, a fertilizing influence upon the pistillidia, it being assumed that those bodies, or the fluid which they are bathed in, penetrate down the canal of the style or neck-like portion of the pistillidium to reach the minute cell, the supposed embryonal cell, situated in the globular portion or 'germen' of the pistillidium, and thus render it capable of becoming developed into a perfect fruit.

No such process of fertilization has actually been observed in the Mosses, and therefore all the evidence is at present merely circumstantial; but this is very strong. In the first place it is stated as an undoubted fact by Schimper and Bruch, that in the diœcious Mosses, those on which the antheridia and pistillidia occur in separate plants, fruit is never produced on the so-called male plants, and never on the so-called female unless the males occur in the vicinity; several examples are cited in the work of Schimper above referred to; when the sexes occur alone, the increase of the plant is wholly dependent on the propagation by gemmæ or innovations.

By the discovery of the antheridia and pistillidia in the other higher Cryptogams, the arguments from analogy greatly strengthen the hypothesis of the sexuality of Mosses.

Further observation is required, then, for the direct proof of the occurrence of a process of fertilization in the Mosses; but the facts now before us all tend to prove their sexuality if we argue from analogy, and the probabilities deduced from the negative evidence above referred to in regard to the diœcious species.

It is unnecessary to give any account of the well-known structure of the Moss capsules; yet in order to render the comparison with the phænomena of the life of Mosses with those of the other leafy Cryptogams complete, it may be worth while to allude to the germination of the spores. The spore is a single cell, with a double coat, like a pollen-grain; this germinates by the protrusion of the inner coat in the form of a filamentous or rather tubular process, which grows out and becomes subdivided by septa so as to form a confervoid filament. The lateral branches bud out from some of the cells, some elongating into secondary filaments, others at once undergoing a more active development, and by the multiplication of their cells, assuming the condition of conical cellular masses, upon which the forms of Moss leaves may soon be detected; these cellular masses becoming buds from which the regular leafy stems arise.

Hepaticæ.—The genera comprehended in this family present a wonderful variety of structure in the reproductive organs, but in almost all of them the existence of the two kinds of organs called pistillidia and antheridia have long been demonstrated, and in most cases the development of the sporangia from the so-called pistillidia has been traced. In those genera in which the plants most resemble the Mosses in the vegetative portion, as in *Jungermanniæ*, the pistillidia are very like those of the Mosses; this is also the case in *Marchantia*; but in *Pellia*, *Anthoceros* and other genera, the rudiment of the sporangium bears a striking resemblance to the so-called ovules of the Ferns, Rhizocarpeæ, &c. occurring upon the expanded fronds very much in

the same way as those bodies do upon the pro-embryos of the said families. It would occupy too much space to enter into a minute detail of the various conditions that are met with. It is sufficient to say that in all cases the physiological stages are analogous to those of the Mosses; since the pistillidia produced upon the fronds or leaf-bearing stems developed directly from the spores, go on to produce a *sporangium alone*, in which the new spores are developed, without the intervention of the stage of existence presented by the pro-embryo of the Ferns and Equisetacæ, where the pistillidia and antheridia occur upon a temporary frond, and the former give origin to the regular stem and leaves of the plant.

Ferns.—This class formed for a long time the great stumbling-block to those who sought to demonstrate the existence of sexuality in the Cryptogamous plants. The young capsules were generally considered to be the analogues of the pistillidia of the Mosses, and the young abortive capsules which frequently occur among the fertile ones were supposed by some authors to represent the antheridia. Mr. Griffith*, shortly before his death, noticed a structure which he was inclined to regard as the analogue of the antheridium in certain of the ramenta upon the petioles.

In the year 1844, Prof. Nägeli† published an account of his observations on the germination of certain Ferns, and announced the discovery of moving spiral filaments closely resembling those of the Charæ, on certain cellular structures developed upon the pro-embryo or cellular body first produced by the spore. It is not worth while to enter into an analysis of his observations, as they have since been clearly shown to have been very imperfect; it is sufficient to state that he only described *one* kind of organ, and from his description it is evident that he confounded the two kinds since discovered, regarding them as different stages of one structure. The announcement of this discovery seemed to destroy all grounds for the assumption of distinct sexes, not only in the Ferns but in the other Cryptogams, since it was argued that the existence of these cellular organs, producing moving spiral filaments, the so-called spermatozoa, upon the germinating fronds, proved that they were not to be regarded as in any way connected with the reproductive processes.

But an essay published by the Count Suminski‡ in 1848 totally changed the face of the question, and opened a wide field for speculation and investigation on this subject, just as it was beginning to fall into disfavour. Count Suminski's paper gives a minute history of the course of development of the Ferns from the germination of the spore to the production of the regular fronds, and he found this development to exhibit phænomena as curious as they were unexpected. The cellular organs seen by Nägeli were shown to be of two perfectly distinct kinds, and moreover to present characters which gave great plausibility to the hypothesis that they represented reproductive organs; moreover, this author expressly stated that he had obtained absolute proof of sexuality by observing an actual process of fertilization to take place in the so-called ovules, through the agency of the spiral filaments or spermatozoa.

The main points of his paper may be briefly summed up as follows. The Fern spore at first produces a filamentous process, in the end of which cell-development goes on until it is converted into a Marchantia-like frond of small size and exceedingly delicate texture, possessing hair-like radicle hairs on its under side. On this under side become developed, in variable num-

* Posthumous Papers, Journal of Travels, 444.

† Zeitschrift für Wiss. Botanik, Heft 1. Zurich, 1844.

‡ Zur Entwickelungsgeschichte der Farrenkräuter. Berlin, 1848.

bers, certain cellular organs of two distinct kinds. The first, which he terms antheridia, are the more numerous, and consist of somewhat globular cells, seated on and arising from single cells of the cellular Marchantia-like frond. The globular cell produces in its interior a number of minute vesicles, in each of which is developed a spiral filament, coiled up in the interior. At a certain epoch the globular cell bursts and discharges the vesicles, and the spiral filaments moving within the vesicles at length make their way out of them and swim about in the water, displaying a spiral or heliacal form, and consisting of a delicate filament with a thickened clavate extremity; this, the so-called head, being said by Count Suminski to be a hollow vesicle, and to be furnished with six or eight cilia, by means of which the apparently voluntary movement of the filament is supposed to be effected.

The second kind of organ, the so-called 'ovules,' are fewer in number and present different characters in different stages. At first they appear as little round cavities in the cellular tissue of the pro-embryo, lying near its centre and opening on the under side. In the bottom of the cavity is seen a little globular cell, the so-called embryo-sac. It is stated by Count Suminski that while the ovule is in this state one or more of the spiral filaments make their way into the cavity, coming in contact with the central globular cell. The four cells bounding the mouth of the orifice grow out from the general surface into a blunt cone-like process, formed of four parallel cells arranged in a squarish form and leaving an intercellular canal leading down to the cavity below. These four cells become divided by cross septa, and grow out until the so-called ovule exhibits externally a cylindrical form, composed of four tiers of cells, the uppermost of which gradually converge and close up the orifice of the canal leading down between them. Meanwhile the vesicular head of one of the spiral filaments has penetrated into the globular cellule or embryo-sac, enlarged in size and undergone multiplication, and in the course of time displays itself as the embryo, producing the first frond and the terminal bud whence the regular Fern stem is developed. In considering the import of these phænomena, the author assumes the analogy here to be with the process of fertilization in flowering plants, as described by Schleiden, regarding the production of the embryo from the vesicular head of the spermatozoa as representing the production of the phanerogamous embryo from the end of the pollen tube after it has penetrated into the embryo-sac.

The promulgation of these statements naturally attracted great attention, and since they appeared we have received several contributions to the history of these remarkable structures, some confirmatory, to a certain degree, of Suminski's views, others altogether opposed to them.

In the early part of 1849 Dr. Wigand* published a series of researches on this subject, in which he subjected the assertions of Suminski to a strict practical criticism; the conclusions he arrived at were altogether opposed to that author's views respecting the supposed formation of the organs, and he never observed the entrance of the spiral filaments into the cavity of the so-called ovule.

About the same time M. Thuret† published an account of some observations on the antheridia of Ferns. In these he merely confirmed and corrected the statements of Nägeli respecting the antheridia, and did not notice the so-called ovules.

Towards the close of the same year, Hofmeister‡ confirmed part of

* Botanische Zeitung, vol. vii. 1849.

† Ann. des Sc. Nat. Jan. 1849. ser. 3. vol. xi. Botanique. ‡ Botanische Zeitung, 1849.

Suminski's statements and opposed others. He stated that he had observed distinctly the production of the young plant (or rather the terminal bud for the new axis), in the interior of the so-called 'ovule,' but believed the supposed origin of it from the end of the spiral filament to be a delusion. He regards the globular cell at the base of the canal of the 'ovule' as itself the rudiment of the stem, or embryonal vesicle (the embryo originating from a *free* cell produced in this), analogous to that produced in the pistillidia of the Mosses. He also describes the development of the ovule differently, saying that the canal and orifice are opened only at a late period by the separation of the contiguous walls of the four rows of cells.

About the same time appeared an elaborate paper on the same subject by Dr. Hermann Schacht*, whose results were almost identical. He found the young terminal bud to be developed in the cavity of one of the so-called 'ovules,' which were developed exactly in the same way as the pistillidia of the Mosses. He stated also that the cavity of the 'ovule' is not open at first, and he declares against the probability of the entrance of a spiral filament into it, never having observed this, much less a conversion of one into an embryo.

In the essay of Dr. Mettenius already referred to†, an account of the development of the so-called ovules is given. His observations did not decide whether the canal of the 'ovule,' which he regards as an intercellular space, exists at first, or only subsequently, when it is entirely closed above. Some important points occur in reference to the contents of the canal.

The contents of the canal in a mature condition consist of a continuous mass of homogeneous, tough substance, in which fine granules, and here and there large corpuscles, are imbedded. It reaches down to the globular cell or 'embryo-sac,' and is in contact with this. This mass either fills the canal or diminishes in diameter from the blind end of the canal down to the 'embryo-sac;' in other cases it possesses the form represented by Suminski, having a clavate enlargement at the blind end of the canal, and passing into a twisted filament below. In this latter shape it may frequently be pressed out of isolated 'ovules' under the microscope, and then a thin transparent membrane-like layer was several times observed on its surface. In other cases the contents consisted of nucleated vesicles, which emerged separately or connected together.

The embryo-sac consists of a globular cell containing a nucleus, and this author believes that the commencement of the development of the embryo consists in the division of this into two, which go on dividing to produce the cellular structure of the first frond.

With regard to the contents of the canal the author says,—

"Although I can give no information on many points, as in regard to the origin of the contents of the canal of the 'ovule,' yet my observations on the development of the 'ovule' do not allow me to consider them, with Suminski, as spiral filaments in course of solution; just as little have I been able to convince myself of the existence of the process of impregnation described by that author. It rather appears to me that the possibility of the entrance of the spiral filaments and the impregnation cannot exist until the tearing open of the blind end of the canal in the perfectly-formed ovule, as after the opening of the so-called 'canal of the style' in the pistillidia in the Mosses."

Another contribution has been furnished by Dr. Mercklin‡, the original of

* Linnæa, vol. xxii. 1849.

† Beiträge zur Botanik, 1. Heidelberg, 1850. Zur Fortpflanzung der Gefäss-Cryptogamen.

‡ Beobachtungen aus dem Prothallium der Farrenkräuter. St. Petersburg, 1850.

which I have not seen, but depend on analyses of it published in the 'Botanische Zeitung*,' and the 'Flora' for 1851†, and further in a letter from Dr. Mercklin to M. Schacht‡, which appeared in the 'Linnæa' at the close of last year.

He differs in a few subordinate particulars from M. Schacht in reference to the development and structure of the *prothallium* or pro-embryo, and of the antheridia and spiral filaments; but these do not require especial mention, except in reference to the vesicular end of the spiral filament described by Schacht, which Mercklin regards as a remnant of the parent vesicle, from which the filament had not become quite freed. The observations referring to the so-called ovule and the supposed process of impregnation are very important; they are as follows:—

"1. The spiral filaments swarm round the 'ovule' in numbers, frequently returning to one and the same organ.

"2. They can penetrate into the 'ovule.' This was seen only three times in the course of a whole year, and under different circumstances; twice a spiral filament was seen to enter a still widely open young 'ovule,' then come to a state of rest, and after some time assume the appearance of a shapeless mass of mucilage; the third case of penetration occurred in a fully-developed 'ovule,' through its canal; it therefore does not seem to afford evidence of the import of the spiral filament, but certainly of the possibility of the penetration.

"3. In the tubular portion of the 'ovule,' almost in every case, peculiar club-shaped, granular mucilaginous filaments occur at a definite epoch, these filaments, like the spiral filaments, acquiring a brown colour with iodine. These mucilaginous bodies sometimes exhibit a twisted aspect, an opake nucleus, or a membranous layer, peculiarities which seem to indicate the existence of an organization.

"4. These club-shaped filaments are swollen at the lower capitate extremity, and have been found in contact with the 'embryo-sac' or globular cell which forms the rudiment of the future frond.

"5. The spiral filaments, which cease to move and fall upon the prothallium, are metamorphosed, become granular and swell up."

Hence the author deduces the following conclusions:—

"That these clavate filiform masses in the interior of the 'ovule' are transformed spiral filaments, which at an early period, while the ovule was open, have penetrated into it; which leads to the probability that—

"1. The spiral filaments must regularly penetrate into the 'ovules,' and

"2. They probably contribute to the origin or development of the young fruit frond (or embryo). In what way this happens the author knows not, and the details on this point given by Count Suminski remain unconfirmed facts."

An important point in this essay is the view the author takes of the whole process of development in this case. He regards it as not analogous to the impregnation in the Phanerogamia, since the essential fact is merely the development of a *frond* from one cell of the *prothallium*, which he considers to be merely one of the changes of the individual plant; while all the other authors who have written on the subject, with the exception of Wigand, call the first frond, with its bud and root, an *embryo*, and regard it as a new individual, or at all events a distinct member of a series of forms constituting collectively the representatives of the species.

* Botanische Zeitung, vol. xxxiii. 1850. † Flora, vol. xxxiii. p. 696. 1850.
‡ Linnæa, vol. xxiii. p. 723. 1850.

Finally, Hofmeister, in his notice of this essay in the 'Flora *,' declares that the development of the so-called 'embryo' or first frond commences, not by the subdivision of the globular cell or 'embryo-sac,' but by the development of a free cell or 'embryo vesicle' in this, like what occurs in the embryo-sac of the Phanerogamia; and he asserts that this is the first stage of development from the globular cell in all the vascular Cryptogams, including that found in the pistillidia of the Mosses.

Equisetaceæ.—The first discovery of the analogy between the developments from the spore in germination, in the Ferns and Equisetaceæ, is due to M. G. Thuret †, who saw the spores of the latter produce a cellular pro-embryo somewhat like that of the Ferns, and in this were developed antheridia of analogous structure, emitting cellules containing many spiral filaments.

This announcement was confirmed by M. Milde ‡, whose observations extended over some months, during which time no 'ovule' was produced, but he saw what appeared to be the rudiment of one. Dr. Mettenius § states that he has met with decaying 'ovules' precisely like those of the Ferns, upon the pro-embryo of an Equisetum, and thus the evidence is completed, so far as the occurrence of the two kinds of organs is concerned.

Lycopodiaceæ.—The fructification of this family consists, as is well known, of spikes clothed with fruit-leaves, bearing on their inner faces sporangia containing spores. These spores are of two kinds. One sort occur in large numbers in their sporangium, and are very small; the others are much larger, and only four are met with in a sporangium. Spring ||, who has devoted great attention to the general characters of the Lycopodiaceæ, has given especial names to the two kinds of sporangia; those with the four large spores he calls oophoridia, those with the small spores antheridia; yet he did not mean to attribute a sexual antithesis, merely a morphological one, as he expressly states.

The general impression however with regard to the import of the two kinds of spores has long been, that the large spores alone are capable of producing new plants, and five years ago Dr. C. Müller published an elaborate account of the development of the Lycopodiaceæ ¶, in which the germination of the large spores was described at length. The following are the essential results of his investigations.

The large spores are more or less globular bodies, usually flattened on the surfaces by which they are in contact in the oophoridium; thus, while the outer side has a spherical surface, the inner side has three or four triangular surfaces, as in *L. selaginoides*, and *L. denticulatum*. They possess two coats, the outer very thick and composed of numerous cells, the cavities of which are almost completely filled up by deposits of secondary layers. This outer coat exhibits various forms of raised markings on its outer surface, and in some cases these seem to form a distinct layer, a kind of cuticle, capable of being separated from the subjacent cells. The inner coat of the spore is *usually* perfectly structureless, and not very firmly attached to the outer coat. In *L. gracillimum* Dr. Müller observed below the outer coat a structure composed of a layer of rather large parenchymatous cells, which could be easily isolated; and as there was no structureless membrane within this, he regarded the layer as the proper inner coat. This observation is important in relation to the discrepancies between Dr. Müller's statements and those of Mettenius,

* 1850, p. 700. † Ann. des Sc. Nat. 1849, vol. xi. 5. ‡ Linnæa, 1850.
§ Beiträge zur Botanik, 1850, p. 22. || Flor. Brasiliensis, 106–108.
¶ Botanische Zeitung, July 31, 1846, *et seq. num.* Ann. of Nat. History, vol. xix. 1847.

to be spoken of presently. The cavity of the spore is filled with granular mucilage.

When the spore is placed in favourable circumstances for germination it begins to swell up, and if the contents be examined with the microscope, a few minute cells will soon be found to have become developed in the mucilage. This cell-formation commences at a determinate spot upon the inner coat of the spore, the cells being so firmly applied that they appear blended with this inner membrane. The cell-formation goes on till an obtuse conical process is developed, which breaks through the outer tough coat of the spore, and this process is recognized as the germinal body or *keim-körper*, corresponding to the pro-embryo of the other Cryptogams. From this, which at this period does not by any means fill the cavity of the spore with its lower portion, an ovate process is produced, at first obliquely directed upwards, the bud of the future stem, and a conical process taking the opposite direction representing the radicle. On the ascending process a distinction can soon be observed between the terminal bud, a little oval body, and a short thread-like stem on which it is supported; as the bud opens, the leaves appear in pairs.

At the conclusion of the paper Dr. Müller offers some remarks on the evidence with respect to the import of the spores, the substance of which may be transcribed. "Up to the present time it remains doubtful what purpose is served by the antheridium-spore. Some persons maintain one opinion, others another. One author declares he has seen it germinate, another that he has never been able to do so. Kaulfuss* relates that Fox sowed *Lyc. Selago*, and Lindsay *L. cernuum* with success, and that *L. clavatum* sprung up abundantly with Willdenow. With himself it did not succeed; but the garden-inspector, Otto of Berlin, raised *L. pygmæum* several years in succession from seed. The last case however is readily explicable, since *L. pygmæum* possesses oophoridia."

Göppert† however states that he has seen the development of young plants from antheridium-spores in *L. denticulatum*. Dr. Müller expresses some doubt as to whether the observation was absolutely exact, since Göppert never mentions seeing a young plant actually adherent to an antheridium-spore, neither does he give the structure of the leaf, and the young plant he figures closely resembles a *Fissidens*, frequently springing up in flower-pots in green-houses. In his own attempts to raise plants from antheridium-spores, Dr. Müller in every case failed. He does not deny, however, that they may be capable of germination, especially as some Lycopodiaceæ appear to be devoid of oophoridia.

In 1849 appeared M. Hofmeister's notice on the fructification and germination of the higher Cryptogamia‡, in which he indicated the existence on the pro-embryo of *Selaginella*, of a number of peculiar organs, composed of four papilliform cells, enclosing a large globular cell in the centre. In one of these large spherical cells the young plant is produced. The nature of the structure was only briefly described in this paper for the purpose of showing its analogy with what occurs in *Salvinia*.

In 1850 Dr. Mettenius§ published an essay on the Propagation of the Vascular Cryptogams, and in this is to be found a full description of the organs mentioned by Hofmeister and altogether overlooked by Dr. C. Müller.

* Das Wesen der Farrenkräuter. Leipzig, 1827.

† Uebers. der Arbeiten und Veränd. der schlesischen Gesellsch. für vaterl. Kultur, 1841 und 1845.

‡ Bot. Zeitung, Nov. 9, 1849.

§ Beiträge zur Botanik. Heidelberg, 1850.

According to this author, the large spores of *Selaginella involvens* possess two coats, each composed of two layers; and in an early stage of the germination, the inner layer of the outer coat, together with the inner coat, form the walls of a globular body which does not wholly fill the cavity enclosed by the outermost membrane. This globular body is firmly attached to the outer membrane immediately under the point of junction of the three ridges separating the flattened surfaces of the inner side of the spore. The globule enlarges until its walls come to be applied closely to the outer layer, completely filling up the large cavity. Then between the two layers of the inner coat, at a point immediately beneath the point of junction of the three external ridges, a process of cell-formation commences, producing a flattened plate of tissue interposed between the two layers; this structure is the pro-embryo. The cells are at first in a single layer, but the central ones soon become divided by horizontal septa so as to produce a double layer, and finally four or more tiers of cells one above another. The outline of the pro-embryo, seen from above, is circular, spreading over the upper part of the spore. On its surface appear the so-called ovules. The first is produced at the apex of the pro-embryo, the rest, to the number of twenty or thirty, arranged upon its surface in three lines corresponding to the slits by which the outer coat of the spore bursts. These ovules, closely resembling those of *Salvinia*, *Pilularia*, the Ferns, &c., consist of a globular cell surmounted by four cells, which rise up into four papillæ, and leave a canal or intercellular passage between them, leading down to the globular cell or embryo-sac. The four cells are usually developed into four or five cells, one above the other, by the production of horizontal septa; sometimes they are developed unequally and to a considerable extent so as to form papillæ, presenting an orifice between them at some point on the outer surface, indicating the canal leading down to the embryo-sac.

During the development of the ovules, a delicate parenchyma is produced in the great cavity of the spore, finally entirely filling up this spore. Before it has completely filled it, the embryo makes its appearance in the embryo-sac of one of the ovules.

The first change in this sac is the appearance of a nucleus; from this cells are developed representing the suspensor of the embryo. The cells of the suspensor multiply and form the process which penetrates down into the parenchyma of the cavity of the spore; at the lower end may be detected the embryo, a minutely cellular body. Dr. Mettenius never saw the embryo produced in the embryo-sac before the suspensor had broken through the bottom of it to penetrate the parenchyma of the spore-cell; it was always within this parenchyma and attached to the end of the suspensor. In this point he is decidedly opposed to Hofmeister, who states that the embryo originates in the embryo-sac, whence a young embryo attached to its suspensor may easily be extracted from the spore.

The part of the embryo opposite to the point of attachment of the suspensor corresponds to the first axis of the Rhizocarpeæ, which never breaks out from the spore-cell in *Selaginella*; it pushes back the loose parenchyma of the spore-cell as it becomes developed, and when completely formed, is surrounded by a thin coat composed of several layers of the parenchymatous cells much compressed, enclosed in the still existing inner coat of the spore. On one side of the point of attachment of the suspensor the embryo grows out towards the point where the spore-cell has been ruptured, thus apparently in a direction completely opposite to the end of the axis. As it enlarges it

produces in this situation the leafy stem growing upwards, and the adventitious root turning downwards. The pro-embryo is at first distended like a sac, and finally broken through on the one side by the first leaf, on the other by the adventitious root; upon it may be observed the numerous abortive ovules, with their embryo-sacs filled with yellow contents; part of its cells grow out into radical hairs. Dr. Mettenius several times saw two young plants produced from one spore; the ends of their axes lay close together, and separated inside the cavity of the spore. No account is here given of the characters exhibited by the small spores, or of anything like a process of fertilization; yet we have indicated in the foregoing description of the so-called ovules, a clear analogy between these bodies and the so-called ovules of the Ferns and Rhizocarpeæ. These points will be referred to again at the close of the report.

In a review of Dr. Mercklin's essay on the reproduction of the Ferns, in the Flora*, Hofmeister states that spiral filaments are produced from the small spores of *Selaginella*, but does not state that he has seen them or give any authority.

Isoëtaceæ.—The spores of the *Isoëtes lacustris* are of two kinds, analogous to those of the Lycopodiaceæ; both kinds being produced in sporangia imbedded in the bases of the leaves, but the large spores are found in great numbers, not merely four in a sporangium as in the Lycopodiaceæ. The development of the spores was little known until the publication of an essay on the subject in 1848, by Dr. C. Müller†, forming a sequel to his researches on the Lycopodiaceæ. Here, as in the other case, his observations on the earlier stages were imperfect; but he indicated the existence of the structures which have since been recognized as the so-called ovules; as also did Mr. Valentine‡ in his essay on *Pilularia*.

In his essay Dr. C. Müller compares the complete large spore, as discharged from the sporangium, to the ovule of flowering plants; and he describes it as a globular sac enclosed by three coats, which he names the primine, secundine, and the nucleus. The outermost coat, or primine, is stated to be composed of a thick cellular membrane exhibiting a raised network of lines, which give it the aspect of a cellular structure, but are in reality analogous to the markings on pollen-grains. The outer surface exhibits the lines indicating the tetrahedral arrangement of the spores in the parent cell, as in *Selaginella*, and it is at the point of intersection of these that the membrane gives way in germination. The next coat, or secundine, is another simple membrane lining the first. The nucleus is a coat composed of delicate parenchymatous cells, but among these are found groups of peculiar character. These are described as consisting of a large cell divided by two septa crossing each other at right angles, projecting from the general surface, being either oval in the general outline, or having four indentations opposite the cross septa, so as to give the appearance of the structure being composed of four spherical cells. The cells surrounding them are of irregular form, different from the generally six-sided cells of the rest of the nucleus. Many of these groups occur on the nucleus, always at the surface of the coat where the primine and secundine afterwards give way, scattered without apparent order over it, but one always near the point of the opening. To these structures Dr. Müller did not attribute any important function, explaining them merely as produced

* Flora, 1850, p. 700.

† Botanische Zeitung, April and May, 1848; Annals of Nat. History, 2nd ser. vol. ii. 1848.

‡ Linnæan Transactions, vol. xvii.

by peculiar thickenings of the tissue to protect the pro-embryo during germination. The contents of the nucleus were stated to resemble those of the cavity of the spores of *Selaginella*.

In these contents, which become dense and mucilaginous, a *free* cell is developed near the upper part of the cavity; this is the rudiment of the embryo, and by cell-multiplication becomes a cellular mass, which soon begins to exhibit growth in two directions, producing the first leaf and the first rootlet, projecting from a lateral cellular mass, which the author calls the "reservoir of nutriment." The embryo then breaks through the coats; the first leaf above and the first root below, the coats remaining attached over the central mass of the embryo. The subsequent changes need not be mentioned here, further than to state that the leaves succeed each other alternately, and are not opposite as in the Lycopodiaceæ; moreover no internodes are developed between them, so that the stem is represented by a flat rhizome, like the base of the bulb of many Monocotyledons.

In the paper by Dr. Mettenius*, already alluded to, we find some very important modifications of and additions to this history of development of the spores of *Isoëtes*, bringing them into more immediate relation with the other vascular Cryptogams.

This author describes the spore-cell as a thick structure composed of several layers; in some cases he counted four. It completely invests the pro-embryo, which is a globular cellular body filling the spore-cell. Among the cells of the outermost layer of the pro-embryo (which layer forms the *nucleus* of Dr. Müller), on the upper part, are produced the ovules, fewer in number than in *Selaginella*, arranged in three rows converging upon the summit of the spore, these rows corresponding to the slits between the lobes of the outer coat of the spore. The four superficial cells of the ovules (which are evidently the peculiar groups mentioned by Müller and previously noticed by Valentine†) grow much in the same way as in the Rhizocarpeæ and in *Selaginella*, into short papillæ. The embryo is developed in the substance of the pro-embryo, displacing and destroying its cells, and a globular portion (corresponding to the "reservoir of nutrition" of Müller) remains within the spore after the first leaf and rootlet have made their way out. This body is the analogue of that portion of the embryo of *Selaginella* which penetrates into the cavity of the spore, and to the end of the first axis in the Rhizocarpeæ.

The most important point, however, of Dr. Mettenius's researches relates to the phænomenon exhibited by the small spores. In the water in which the spores were sown he observed moving spiral filaments resembling those of the Ferns. He was not able to trace all the stages of development of these spiral filaments from the small spores, but he obtained nearly all the evidence relating to their origin which Nägeli has done in reference to the similar organs in the *Pilularia*‡. In the small spores minute vesicles are produced of varying size and number, seen through the outer coat. The inner coat or spore-cell breaks through the outer coat either in the middle or at both ends at the projecting ridges, by which they are originally in contact with the other spore-cells. Its contents are expelled, as is proved by finding numerous empty membranes. The expelled vesicles are met with in considerable number in the water, and contain one large or several small granules, and in them the spiral filaments are apparently produced; but the actual course of development was not observed. In one case a spiral filament was seen half

* Beiträge zur Botanik. Heidelberg, 1850. † Linnæan Transactions, vol. xvii.
‡ Zeitschrift für Wiss. Botanik, Heft 3. Zurich, 1846.

way out of the spore-cell in active rotation, finally emerging completely, so that the moving spiral filaments are probably developed in the vesicles, while these are still contained within the spore-cell.

No actual connexion of these moving spiral filaments or spermatozoa with the so-called ovules has yet been traced.

Rhizocarpeæ.—Almost from the earliest period of the study of Cryptogamous plants, attempts have been made to prove the existence of distinct sexes in the Rhizocarpeæ, various parts of the structure being regarded by different authors as analogues of the stamens and pistils of flowering plants. Bernard de Jussieu* went so far as to class them (*Pilularia glob.* and *Marsilea quad.*) with the Monocotyledons, with *Lemna*, considering the large spore-sacs as pistils and the small ones as stamens.

Others have sought the male organs in the hairs upon the leaves or receptacles†; but the rest of the numerous authors who have written on the subject, have either denied the distinction of sexuality altogether, or are agreed in considering the large spores as either ovaries or ovules, the small spores as pollen-grains. Experiments have frequently been made upon the generative powers of the two kinds of spores. Paolo Savi‡ found that the large spores of *Salvinia* would not germinate alone, and therefore he regarded the small ones as anthers. Duvernoy§, on the contrary, states that he saw the large spores of *Salvinia* germinate when separated from the small ones, and therefore he did not regard the latter as anthers, but only rudiments. Bischoff||, who minutely described the structure of the European species, said that in his experiments the large spores of *Salvinia* germinated as well without the small granules as with them. Agardh¶ saw the large spores of *Pilularia* germinate separately, but later than those united with the anthers. Pietro Savi** made careful observations on the germination of the separated large spores of *Salvinia*, and found them to produce a green mamilla which underwent no further development; he therefore regarded the small spores as necessary for impregnation. Esprit Fabre†† carefully experimented on *Marsilea Fabri*. The separated large spores did not germinate; they did not even produce the stationary green papilla observed in *Salvinia* by Pietro Savi. Dr. C. Müller‡‡ found that the large spores of *Pilularia* would not germinate when separate from the small ones.

The development of the spores and the germination of the larger kind in *Pilularia* appear to have been first accurately described by Mr. Valentine§§, in a paper read before the Linnæan Society in March 1839. It is unnecessary to enter into the particulars of this paper, which gives accurate statements in most points, and mentions for the first time the occurrence of the cellular papilla upon the pro-embryo which has since been regarded as the "ovule," analogous to that found on the pro-embryo of the other vascular Cryptogams.

Dr. C. Muller's|||| essay appeared in 1840, and agrees in some points; but he appears to have mistaken the mode of origin of the pro-embryo. In 1843 Schleiden¶¶ announced that he had observed a process of impregnation in *Pilularia*, in which the small spores acted the part of pollen-grains, producing tubes which entered into a cavity on the surface of the large spore or "ovule," and, in accordance with his views of impregnation in general, became the embryo.

* Hist. de l'Acad. Roy. des Sc. 1739 and 1740.
† Micheli, Linnæus and Hedwig
‡ Biblioth. Italian. xx.
§ Diss. de *Salv. nat.* &c., 1825.
|| Nova Acta xiv. and Cryptogam Gew. part 2. 1828.
¶ De *Pilularia* diss. 1835.
** Ann. des Sc. Nat. 1837.
†† Ann. des Sc. Nat. 1837.
‡‡ Flora, 1840.
§§ Linnæan Transactions, vol. xvii.
|||| Flora, 1840.
¶¶ Grundz. der Wiss. Botanik, 1843.

The next paper on the subject was an essay published by Dr. Mettenius* in 1846, in which the anatomy and development of *Salvinia* is treated at length; that of *Pilularia* and *Marsilea* less perfectly. He did not observe the process of impregnation described by Schleiden, yet from the want of organic continuity between the embryo and the "ovule," he inclined to adopt the theory of fertilization propounded by Schleiden, both for the Phanerogamia and the Rhizocarpeæ, namely, that the end of the pollen-tube penetrated into the so-called ovule and became the embryo; nevertheless he had some doubts, since he could not reconcile the production of "pollen-tubes" from the small spores of *Salvinia* with the facts he had observed, and never saw the "tube" penetrate the "ovule" in *Pilularia*.

In 1846 Prof. Nägeli published some new and important observations on *Pilularia*†, in which he stated that the observations of Schleiden were altogether incorrect, and that the bodies which that author had described as three or four "pollen-tubes," produced by the small spores and adherent to the summit of the large spore, were in fact parts of this, constituting a papilliform structure, forming a part of the pro-embryo developed by the large spore itself. Moreover he discovered a totally unexpected fact in regard to the small spore or "pollen-grains." He found that these, without coming in contact with the large spores at all, became elongated by the inner coat protruding like a short pouch-like process through the outer. This contained starch-granules; and some he found burst and surrounded by starch-grains exactly like those inside the others; and in addition to these, minute cellules which seem to have been expelled from the small spores. In these cellules were developed spiral filaments exhibiting active movement, just like those of *Chara*, the Mosses, &c. These filaments finally make their way out and swim about freely in the water. They were constantly met with in the gelatinous mass in which the spores were enveloped.

In 1849 M. Hofmeister‡ published the essay on the higher Cryptogams already alluded to, and there briefly described his own critical observations, referring to the points of difference from his predecessors. His statements are as follows:—

"The publications of Mettenius and Nägeli, as also those of Schleiden himself, sufficiently show that the large spores of the Rhizocarpeæ (the organs called by Schleiden 'seed-buds' (ovules)) originate essentially in the same way as the spores of the Cryptogamia generally, and as the small spores of the Rhizocarpeæ ('pollen-grains' of Schleiden) in particular. One young spore in each *sporangium* becomes developed more rapidly than the others, and finally usurps the whole cavity. At the time when the spores are ripe, a large spore does not differ from a small one in any respect except in dimensions (the size of the organs allows of the structure of the outer secreted layer being very distinctly observed; in *Pilularia* five layers can be clearly detected). The large spore is a simple tough-walled cell filled with starch or oil-drops and albuminous matter, enclosed by a thick *exine*, which, at the point when the 'sister-spores' were in contact with the developed spore in the earlier stages, exhibits peculiar conditions of form, displaying, according to the generic differences, a splitting into thin lobes or a considerable thinning of the mass. Not the least trace of the cellular body (the pro-embryo, *papilla of the nucleus* of Schleiden) is to be seen at this point at the time when the spores are just ripe.

* Beiträge zur Kenntniss der Rhizocarpeæ. Frankfort, 1846.
† Zeitschrift für Wiss. Botanik. Heft 3, 4. 188, 1846.
‡ Botanische Zeitung, vol. vii. 1849; Botanical Gazette, vol. ii. 1850.

"After the ripe spores have lain a longer or shorter time in water, a process of cell-formation commences at that point of the spore, *within* the proper, internal spore-cell, whence results the formation of a cellular body occupying only a small portion of the internal cavity of the spore. The cells multiply rapidly, and break through the *exine*, appearing externally as the green cellular papilla called the '*keim-wulst*' by Bischoff, the 'papilla of the nucleus' by Schleiden. I see no ground why this should be named otherwise than as the *pro-embryo*. In *Pilularia* it is very soon seen, where the pro-embryo consists of only about thirty cells, completely enveloped by the *exine*, and where the only external evidence of its existence is a little protuberance,—that the pro-embryo consists of a large central cell surrounded by a simple layer of smaller ones. The smaller cells covering the apex of this large cell, four in number, elongate into a papilla before the pro-embryo bursts through the *exine*, which splits regularly into twelve to sixteen teeth;—subsequently they become divided by horizontal walls, and then appear as the organ which Schleiden, and after him Mettenius, supposed to be 'pollen-tubes' produced from some of the small spores. These papilliform cells most certainly originate from the pro-embryo, a fact which takes away all material ground from Schleiden's theory.

"The four papilliform cells separate from each other and leave a passage leading to the large central cell. In this cell the young plant originates shortly after the smaller spores, which *never* produce 'pollen-tubes,' begin to emit the cellules containing spiral filaments discovered by Nägeli. I observed and dissected out an embryo consisting of only four cells. It completely filled the large central cell, and there was not the least trace of a pollen-tube attached to it.

"The organization of *Salvinia* is somewhat different from this. On every pro-embryo several, as many as eight cells of the outer surface of the cellular layer next but two to the obtuse triangular cellular body, acquire a considerable size, a spherical form, and become filled with protoplasm; the four cells covering each of these larger cells lose the greater part of their chlorophyll and separate from each other to leave a passage leading down to the large central cell. In this large cell the young plant originates. The number of these organs in *Salvinia* allows the possibility of the occurrence of poly-embryony in this genus; I observed two embryos on one pro-embryo in one case.

"It is out of the question to talk of a 'larger pollen-tube' in *Salvinia*. Mettenius has already shown that the structure of the small spores renders such a product from them impossible."

Dr. Mettenius's Essay on the Vascular Cryptogams*, already frequently referred to, confirms the preceding account in all essential points, some slight criticisms relating only to the structure of the coats of the spore; and it adds a description of the development of the "ovules" in the pro-embryo of *Marsilea Fabri*, which agrees closely with that in *Pilularia*. Hofmeister† has recently announced the discovery of the production of cellules containing spiral filaments from the small spores in *Salvinia*, just as Nägeli saw them in *Pilularia*.

General Conclusions.

In the facts of which I have given confessedly a very imperfect *resumé* in the preceding pages, we have two important points to consider. In the first place, we have to determine how far they suffice to warrant the belief in the

* Beiträge zur Botanik. Heidelberg, 1850.

† Flora, 1850. p. 700 (in a note to a review of Mercklin's Essay on the Reproduction of Ferns).

existence of a distinction of sexes in these families. In the second place, we have to endeavour to trace the analogies which exist between the different conditions presented by the supposed sexual organs in the different families. These considerations, if we adopt the hypothesis of sexuality, lead to some very interesting questions in reference to the process of reproduction generally.

In regard to the first question, that of the existence of two sexes and the necessity of a process of fertilization, we have several kinds of evidence.

1. The inferences to be deduced from the universality of the existence of two kinds of organs in connexion with the reproductive process. We have seen that these exist in all the families at some period or other of the life of the representative of the species. In the Mosses and the Hepaticæ they occur in the fully developed plant. In the Ferns and Equisetaceæ they occur upon cellular structures of frondose character developed from all the spores, which frondose bodies or pro-embryos have an existence of some permanence, especially in the Equisetaceæ. In the Lycopodiaceæ, the Isoëtaceæ and Rhizocarpeæ, the pistillidia occur upon very transitory cellular structures produced from one kind of spore, the larger, while the smaller spores at once develope in their interior cellules containing moving spiral filaments such as occur in the antheridia of the other families.

2. The inferences to be deduced from the observations on the development of those plants in which the two kinds of organs, occurring in distinct places, can be separated. Strong evidence has been brought forward that the diœcious Mosses, as they are called, do not produce sporangia when the pistillidia are kept apart from the antheridia by natural accident. The majority of observers state that the large spores of the Rhizocarpeæ do not germinate if the small spores are all removed from contact with them; a few counter-statements however do exist. Again, the majority of authors, and all the recent ones, state that only the large spores of the Lycopodiaceæ and Isoëtaceæ produce new plants; while some older writers believed that they had seen the small spores do so.

3. The direct observation of a process of fertilization, of which we have only testimony from two authors, Suminski and Mercklin, in reference to the Ferns alone; since the assertions of Schleiden in regard to the Rhizocarpeæ have been demonstrated by Nägeli, Hofmeister, and Mettenius to have been based on very imperfect observation.

The circumstantial evidence furnished under the first head seems to me very strong, so much so that I am inclined to adopt the idea of sexuality on this ground as the legitimate provisional hypothesis arising out of our present knowledge, especially when supported so strongly as it is by the negative evidence indicated under the second head.

The positive evidence of the third head is certainly very insufficient as yet, considering the extreme delicacy of the investigation. Suminski's other observations on the details have been contested in many particulars; and Mercklin, the only other observer who asserts that he has seen the spiral filaments within the so-called ovules, describes the conditions differently, and states that he has only been able to observe them positively there three times. At the same time the difficulty of the investigation should make us hesitate in attaching too much weight to the failure of the other observers in tracing a process of fertilization; moreover it is quite possible that actual entry of the spiral filaments into the canal of the ovules or pistillidia is not always, if ever, necessary.

The facts before us, then, appear to me strong enough to warrant the adoption of the views propounded by the latest authors on this subject, and

the acceptance of the hypothesis of sexuality in the Vascular Cryptogams as the most satisfactory explanation of the phænomena as yet observed. The question lies now much in the same condition as that of the sexuality of flowering plants before the actual contact of the pollen-tubes with the ovules had been satisfactorily demonstrated.

Further arguments may be adduced from grounds lying out of the preceding statements, viz. 1. The late discovery of two forms of organs in the Algæ, Lichens and Fungi, which, although imperfect at present, lead to the expectation that the analogues of the antheridia and pistillidia of the Mosses, so long known, will be found in all Cryptogamous plants. 2. The analogies between the processes of animal and vegetable reproduction which appear to be offered by these new views of the nature of the phænomena in the Vascular Cryptogams. To this last argument I shall merely allude, as it may be considered to lie beyond the special province of the vegetable physiologist; yet when we recollect the imperceptible character of the gradations of the lower forms of the two kingdoms, there seems far sounder ground than is allowed by Schleiden for arguing from apparent analogies between the phænomena occurring in the two great kingdoms of nature.

Under the second point of view mentioned above, the facts of structure may soon be disposed of, so far as the analogies of form are concerned; the antheridia of the Mosses, Hepaticæ, Ferns, and Equisetaceæ agree with the small spores of *Isoëtes*, *Selaginella*, *Pilularia*, and *Salvinia* in producing the cellules in which are developed the moving spiral filaments which constitute the essential character of the organs of the one kind; while the pistillidia of the Mosses and Hepaticæ agree with the so-called "ovules" of the Ferns, Equisetaceæ, Lycopodiaceæ, Isoëtaceæ, and Rhizocarpeæ, in general structure and in the presence of the central large cell from which the new form of structure originates.

The great differences depend on the position in time and space of the organs, in the different classes, and the nature of the immediate product of the so-called "embryo-sac," the large central cell of the pistillidia and "ovules."

In the Mosses and Hepaticæ the pistillidia occur upon the plant when the vegetative structure is perfect,—and the immediate product of the great cell is a sporangium. If a process of fertilization take place here, we may regard the antheridia and pistillidia as analogues of the anthers and pistils of flowering plants, the sporangia of their fruits; or with Hofmeister we may regard the phænomenon as an instance of an "alternation of generations," where the pistillidium would be looked upon as an ovule, producing (in the sporangium) a new individual of totally different character from that developed from the spore (the leafy Moss plant in the usual acceptation of the term).

In the Ferns and Equisetaceæ, we find the spores producing a frondose structure of definite form, upon which are developed antheridia and pistillidia, or "ovules." Here then we seem to have one generation complete, and the new development from the pistillidium or "ovule" appears in a totally new form, producing stem and leaves which have a distinct individual form and existence, and produce the spores after a long period upon temporary parts of the structure, on the leaves; and by no means cease to exist when those are matured. Here we seem to have a real "alternation of generations," and Hofmeister compares the whole permanent plant of the Fern or *Equisetum* to the sporangium of the Mosses and Hepaticæ. In all the other families, the Lycopodiaceæ, Isoëtaceæ, the Rhizocarpeæ, the pro embryo is a very transitory production, and is developed from a differen spore from the spiral filaments. This pro-embryo is clearly analogous to

that of the Ferns and Equisetaceæ; and if the existence of sexes be a fact, we have here a diœcious condition as contrasted with a monœcious condition in the two last-named families. Hofmeister here again assumes that the pro-embryo developed from the large spore is an intermediate generation between the two perfect forms of the plant.

It is rather difficult to decide upon the real analogies of these structures with those of the flowering plants. The resemblance of structure is so close between the pistillidia of the Mosses and Hepaticæ, and the "ovules" of the other Vascular Cryptogams, that they must be regarded as analogues, and then the former could not well be conceived to be analogous to the pistils of flowering plants, but rather to ovules; if this be the case, the sporangium must be considered the analogue of the perfect plant in the Fern, &c., and the leafy stem as the analogue of the pro-embryo of the Ferns, &c. The pistillidium of the Mosses can indeed hardly be regarded as analogous to the fruit of a flowering plant, as in that case the spores would be ovules produced long after fertilization; and on the other hand, if we consider the pistillidia of the Moss as an ovule, which it might be, analogous to that of the Coniferæ,—in which a large number of embryonal vesicles or rudiments of embryos are produced after fertilization on the branched extremities of the suspensors,—then we seem to lose the analogy between the product of the pistillidium of the Moss and that of the ovule of the Fern, unless we would regard the entire plant of a perfect Fern as analogous to the ovule of a Conifer.

Perhaps the time has hardly come for us to arrive at any conclusion on these points. The phænomena in the Ferns and Equisetaceæ, as well as in the Rhizocarpeæ, Lycopodiaceæ, and Isoëtaceæ less strikingly, seem to present a series of conditions analogous to those which have been described under the name of "alternation of generations" in the animal kingdom, and seeing the resemblance which the pistillidia of the Mosses have to the ovules of the other families, we can hardly help extending the same views to them; in which case we should have the remarkable phænomenon of a compound organism, in which a new individual forming a second generation, developed after a process of fertilization, remains attached organically to the parent, from which it differs totally in all anatomical and physiological characters. It is almost needless to advert to the essential difference between such a case and that of the occurrence of flower-buds and leaf-buds on one stem in the Phanerogamia, as parts of a single plant, yet possessing a certain amount of independent individuality. These are produced from each other by simple extension, a kind of gemmation; while the Moss capsule, if the sexual theory be correct, is the result of a true *reproductive* process*.

In conclusion, I may remark, that these anomalous conditions lose their remarkable character to a great extent if we refuse to accept the evidence of sexuality which has been brought forward here. If the structures are all products of mere extension or gemmation, the analogies which have been supposed to exist between them and the organs of flowering plants all fall to the ground. But believing that the hypothesis of sexuality is based on solid grounds, I am by no means inclined to allow the difficulty of the ex-

* Moreover we have an analogy to the increase by buds in the *innovations* by which the leafy stems of the Mosses are multiplied, both in the earliest condition, where a number of stems are developed from the byssoid mass produced by the spore, and afterwards by gemmæ on the stems and leaves, as in the Liverworts also. The byssoid mass produced by the Moss-spore has usually been called the *pro-embryo*, but it is evidently not analogous to the bodies termed pro-embryos in the Ferns, Lycopodiaceæ, &c. &c. It would almost seem to constitute a third member of a series of generations.

planation of these relations to be urged as a valid argument against their existence, and I trust that this imperfect report may be the means of attracting new investigators to a subject which presents so many points of interest and importance.—*July 3rd*, 1851.

Postscript.—Since the above Report has been in print Dr. W. Hofmeister has published his promised work upon the higher Cryptogams*, which contains an elaborate series of researches upon this subject. He there confirms all his previous statements, and all the essential particulars given by Suminski, Nägeli, Mettenius, &c., excepting the *facts* of the impregnation by means of the spiral filaments or spermatozoids, which however he considers it warrantable to *assume*. His speculations as to the relation of the Conifers to the Lycopodiaceæ, as shown by the development of the embryo, are very interesting. We can only claim space to indicate the general results of his work as given in the concluding summary:—"The comparison of the course of development of the Mosses and Liverworts on the one hand, with the Ferns, Equisetaceæ, Rhizocarpeæ and Lycopodiaceæ on the other, reveals the most complete agreement between the development of the fruit of the former and the development of the embryo of the others. The archegonium of the Mosses, the organ within which the rudiment of its fruit is formed, resembles perfectly in structure the archegonium of the Filicoids (in the widest sense), that part of the prothallium in the interior of which the embryo of the frondescent plant originates. In the two great groups of the higher Cryptogams, one large central cell originating free in the archegonium, gives origin by repeated subdivision to the fruit in the Mosses, and to the leafy plant in the Filicoids. In neither of them does the subdivision of this cell go on, in both does the archegonium become abortive, if spermatic filaments do not reach it at the epoch when it bursts open at the apex.

"Mosses and Filicoids thus afford one of the most striking examples of a regular alternation of two generations widely different in their organization. The first of these, produced by the germinating spore, developes antheridia and archegonia, sometimes few, sometimes many. In the central cell of the archegonium, in consequence of a fertilization through the spermatozoids emitted from the antheridia, becomes developed the second generation, destined to produce spores, which are always formed in a number much greater than that of the rudimentary fruits of the first generation.

"In the Mosses the vegetative life is exclusively committed to the first, the production of fruit to the second generation. Only the leafy stem possesses roots; the spore-producing generation draws its sustenance from the foregoing. The fruit is usually of shorter duration than the leaf-bearing plant. In the Filicoids the opposite condition obtains. It is true the prothallia send out capillary rootlets; those of the Polypodiaceæ and Equisetaceæ under all circumstances, those of the Rhizocarpeæ and Selaginellæ frequently. But the prothallium has a much briefer existence than the frondescent plant, which in most cases must vegetate for several years before it comes to bear fruit. Yet the contrast is not so strong as it appears to be at first sight. The seemingly unlimited duration of the leaf-bearing Moss-plant depends upon constant renovation (*verjüngung*). Phænomena essentially similar occur in proliferous prothallia of the Polypodiaceæ and Equisetaceæ. The structure of the lowest Mosses (*Anthoceros, Pellia*) is

* *Vergleichende Untersuchungen der Keimung, Entfaltung und Fruchtbildung höherer Kryptogamen* (*Moose, Farrn, Equisetaceen, Rhizocarpeen und Lycopodiaceen*) *und der Samenbildung der Coniferen.* 1851, Leipsic, Hofmeister, 4to, pp. 180, *tt.* 33.

less complex, and the duration of the fruit-bearing shoots is little longer than that of the fruit itself. On the other hand, the ramification of the prothallium of the Equisetaceæ is exceedingly complicated; its duration is even equal to that of a single shoot.

"It is a circumstance worthy of notice, that in the second generation of Mosses, as of the Filicoids, destined to produce spores, more complex thickenings of the cell-walls regularly occur (teeth of the peristome of Mosses, wall of capsule and elaters of Liverworts, vessels of Filicoids, &c.), while in the first generation, springing from the spores, such structures are found only rarely and as exceptions.

"The manner in which the second generation arises from the first, varies much more in the Filicoids than in the Mosses. The Polypodiaceæ and Equisetaceæ are hermaphrodite; the Rhizocarpeæ and Selaginellæ monœcious. All the Filicoids agree in the fact that the first axis of their embryo possesses but a very limited longitudinal development; that it is an axis of the second rank which breaks through the prothallium and becomes the main axis; further, in the end of the axis of the first rank never becoming elongated in the direction opposite to the summit. All Filicoids are devoid of a tap-root, and possess only adventitious roots.

"In more than one respect does the course of development of the embryo of the Conifers stand intermediately between those of the higher Cryptogams and the Phanerogams. Like the primary parent-cell of the spores of the Rhizocarpeæ and Selaginellæ, the embryo-sac is an axile cell of the shoot, which in the former is converted into a sporangium, in the latter into an ovule. In the Conifers the embryo-sac also very early becomes detached from the cellular tissue surrounding it. The filling-up of the embryo-sac with the albumen may be compared with the origin of the prothallium in the Rhizocarpeæ and Selaginellæ. The structure of the 'corpuscula' bears the most striking resemblance to that of the archegonia of *Salvinia*, still more to that of the Selaginellæ. If we leave out of view the different nature of the impregnation, in the Rhizocarpeæ and Selaginellæ by free-swimming spermatic filaments, in the Coniferæ by a pollen-tube (which *perhaps* developes spermatic filaments in its interior), the metamorphosis of the embryonal vesicle into the primary parent-cell of the new plant in the Conifers and Filicoids is solely distinguished, by the latter possessing only a single embryonal vesicle which completely fills the cavity of the central cell of the archegonium, while the former exhibits very numerous embryonal vesicles swimming in it, of which only one pressed into the lower end of the 'corpusculum' becomes impregnated. The embryo-sac of the Conifers may be regarded as a spore which remains enclosed in its sporangium; the prothallium which it forms never comes to light. The fertilizing matter must make a way for itself through the tissue of the sporangium, to reach the archegonia of this prothallium.

"Two of the phænomena which led me to compare the embryo-sac of the Conifers with the large spores of the higher Cryptogams, are common also to the embryo-sac of the Phanerogams: the origin from an axile cell of the shoot, and the independence of the surrounding cellular tissue (so striking, for example, in the Rhinanthaceæ, through the independent growth of the embryo-sac). By their pollen-grains producing tubes the Conifers are closely connected with the Phanerogams, from which they differ so much in the course of development of their embryo-sac and the embryonal vesicles. The separation of the prothallium of the Conifers into a number of independent suspensors, is a phænomenon of a most peculiar kind, having no analogue throughout the vegetable kingdom."—(*Loc. cit.* pp. 139–41.)—A. H. Dec. 16, 1851.

On the Nomenclature of Organic Compounds. *By* Charles G. B. Daubeny, *M.D., F.R.S., Professor of Chemistry at Oxford.*

Introduction.

My attention has of late been in some degree attracted to the nomenclature of organic combinations, and on considering this subject, it has struck me as a matter of surprise, that none of the British treatises on chemistry with which I am acquainted should contain any rules to guide us, either in affixing names to substances newly discovered, or in divining the nature and relations of bodies from the appellations attached to them. Nor do I find this deficiency supplied in a manner which to me appears satisfactory, when I turn to the writings of continental chemists. Amongst these I may mention two in particular, namely Gmelin and Gerhardt, who have busied themselves on this subject; both men of eminence in their respective countries, neither of whom however appears to me to have proposed a scheme of nomenclature at all calculated for general adoption.

Gmelin, indeed, in his Handbook, has invented entirely new names for all simple bodies whatsoever, designating compound ones by means of words made up of those which he had affixed to their constituents. He has even gone further than this, first, in suggesting a method by which the number of atoms of each element may be implied by the inflexion of the name which expresses it; and secondly, in extending the same mode of designation to organic bodies, by the use of distinct terms for each of the supposed radicals, from which, with the addition of certain other elements, the various substances met with in this department of nature are conceived to be built up. Thus for example,—

1 atom of oxygen is expressed by the word *ane*,
2 atoms .... *ene*,
3 atoms .... *ine*,
4 atoms .... *one*,
5 atoms .... *une*,
6 atoms .... *aene*;

and so on.

1 atom of hydrogen is called .... *ale*,
2 atoms, by inflexions of the like description.
1 atom of carbon is called .... *ase*,
——— of sulphur.................... *afe*,
——— of nitrogen .... *ate*,
——— of chlorine .... *ake*,
——— of potass .... *pate*,
——— of soda...................... *nate*;

and so with others. Water will be designated by two syllables, derived from its two constituents, and is therefore called *alan*; sulphurous acid *afen*; sulphuric acid *afin*; sulphate of soda therefore will be *natan-afin*. Arbitrary names are attached to the compound radicals: thus ethyl is *vine*; amyl is *myl*; phenyle is *fune*, &c.

Now it will be seen, that as the new names assigned to the elements bear no relation whatsoever to those in common use, the amount of labour incurred in the adoption of such a nomenclature would be equivalent to that attending the acquisition of a new language, and one too all the more embarrassing from the near resemblance which the words themselves bear to each other. Accordingly I cannot bring myself to believe that such a nomenclature as Gmelin's will ever come into general use; for although it be true, that the

one for inorganic bodies introduced by Lavoisier and his associates, which with all its faults has wonderfully facilitated the advancement of the science, met with rapid success, it must be recollected, that the innovations then made did not extend beyond a few bodies, and those for the most part of recent discovery; whilst even in their case the names imposed were by no means so arbitrary, or so destitute of meaning, as are those of Gmelin.

Oxygen, hydrogen, carbon, and nitrogen, comprise perhaps the entire catalogue of new names for elementary substances devised by the French chemists, and in every one of these the Greek or Latin root of the word suggests some at least of the chemical properties or relations of the body itself.

It is indeed true, that the changes which they introduced pervade the whole of chemistry, because the elements to which new names had been assigned enter so largely into combination with others; but the principles upon which they proceeded in the innovations proposed were nevertheless in themselves few and simple.

Gmelin's method, on the contrary, involves the rejection of the entire system of names in common use, and requires moreover such a perfect familiarity with those which he has substituted, as should enable us to perceive at a glance the import of any combination of them which may occur, and to appreciate the value of each of the inflexions to which the terms are subject, according to the number of atoms which the constituents of the substance designated may severally present. What chemist, for instance, would tolerate such an expression as *natan-afin* for sulphate of soda, or follow the lecturer when he spoke of *lenevine* for wine-alcohol? I have no idea, therefore, that a nomenclature formed upon such a principle as that of Gmelin will ever meet with general adoption, or can be regarded in any other light than as an exercise of ingenuity, or as a kind of philosophical puzzle.

With respect to the other scheme proposed by Gerhardt in his 'Précis de Chemie Organique,' I perhaps need only remark, that such modifications as he has recommended in the established method are founded upon his own peculiar theoretical views, and upon the system of classification which he has thought fit to adopt with respect to organic bodies. Whatever therefore may be its merits, it does not meet the object I have in view, which aims at nothing further than rendering the existing nomenclature more consistent with itself, and with the principles agreed upon by the great body of scientific chemists who are employed upon this department of the subject, and which therefore excludes the adoption of any alterations which imply the recognition of views not yet generally assented to. Moreover, the classification of organic substances with which Gerhardt has set out, is entirely artificial, and one which places bodies belonging to the same type often in the most distant parts of his system; nor has it, to compensate for this defect, the same recommendation which the Linnæan system possesses in Botany, namely, that of enabling us promptly to distinguish the object denoted; since the composition of the body, upon which its place in the series depends, can only be ascertained after a minute and laborious investigation.

But dissatisfied as I may be with the methods hitherto proposed, it is foreign from my intention to suggest any new principle of naming organic substances, convinced as I am that none, except the great masters of the science, who possess influence enough to give laws in the first instance to a numerous band of pupils, and a general reputation so extensive as to cause them to be submitted to afterwards over a much wider circle, have a right to expect that a patient hearing would be given to them, were they to under-

take to originate a System of Nomenclature. All that I aim at accomplishing is to impart, if possible, something like definiteness to our ideas on the subject; and this I propose to do, first by comparing the names assigned by the highest authorities to various organic compounds with the relations in which the bodies themselves stand to each other, and by submitting to you such inferences with respect to the general principles which appear to have guided them in the choice of the terms they employ, as I may have thence deduced; and secondly, by pointing out instances in which the principles assumed appear to have been departed from, and thus anomalies to have been introduced into the language employed.

The plan adopted by the founders of that distinct branch of science now recognised as Organic Chemistry, seems to have been nothing more than an extension of the system common in all similar cases, namely, to select, as a generic name for a class, that of some body belonging to it which happens to be most familiarly known to us. Thus, as the use of the term Salt has been from time immemorial extended, from the substance commonly and best known to us as such, to all that class of bodies which possesses a similar constitution, so in organic chemistry Alcohol is employed as a generic term for a class of bodies, of which spirits of wine is the type; Ether for that of which the body commonly called sulphuric ether is the best known; Camphor for the one to which the well-known product from the *Laurus Camphora* belongs. It is also customary to employ one of the syllables of the word expressive of a class as a part of the name of any particular member of it. Thus chlor*al* is a body of the type of aldehyde, but containing chlorine; *ure*thane, a compound of an ether with an organic base, urea. These indeed may perhaps be regarded rather as abbreviations of the former, than as distinct names for the members of a series.

I shall therefore begin by considering the names applied to those classes under which the multiplied products of natural and artificial processes which present themselves in the domain of organic chemistry have been ranged, at least provisionally, by our systematic writers.

PART I.—*On the Classes of Organic Bodies.*

The following classes of organic bodies appear to be recognized:—

Hydrocarbons.	Alcohols.	Nitriles.
Essential oils.	Aldehydes.	Ureas.
Camphors.	Hydrurets.	Cetones.
Resins.	Ethers.	Glycerides.
Acids.	Amides.	Neutral or indifferent compounds.
Neutral salts.	Imides.	
Alkalies.		

Hydrocarbons.—Hydrocarbon is a term comprehending too miscellaneous a collection of bodies to be of much use for the purposes of classification in the ordinary sense in which it is employed, embracing, as it does, not only the so-called compound radicals, but likewise a large number of the essential oils. As however several of these latter contain in addition oxygen, and others sulphur, such a classification would be inapplicable to a large proportion of the members of this family; and it is also to be considered, that in those oils which consist only of carbon and hydrogen, a portion of the latter principle seems bound to the other element by a looser affinity than the remainder, so that even these may be regarded rather in the light of hydrurets than of simple hydrocarbons. Reserving therefore this latter term for bodies which

stand in the relation of compound radicals, we have three distinct families to set apart from them: namely, essential oils, or eleoptenes; 2nd, camphors, or stearoptenes; and 3rd, resins.

Essential Oils.—Essential oils agree sufficiently in physical and chemical properties to admit of being referred to the same class, notwithstanding such subordinate differences as the superaddition of oxygen, nitrogen, or sulphocyanogen may occasion.

Camphors.—Camphor is a term applied to a class characterized by remaining solid at ordinary temperatures, and by corresponding with the essential oils associated with them in the same plant in the relation between their hydrogen and carbon, the essential difference between the two being the superaddition of an atom of oxygen to the ingredients of the oil.

Resins.—They thus are distinguished from the class of resins, which seem to be derived from the essential oils through the substitution of oxygen for hydrogen. Thus oil of turpentine is represented by $C^{10} H^{8}$; whilst its resin is $C^{10} H^{7} O$, H being removed, O added.

Acids.—With regard to this next class, I am not disposed to recommend any innovation upon existing usage, though aware that Gerhardt has proposed uniting those which contain the elements of water with the neutral salts, distinguishing the former by the generic term usually applied collectively to the whole series of combinations which they contribute to form, and designating the members of each group by specific names taken from those of the several bases united with them.

Thus oil of vitriol would be called normal sulphate, whilst the several combinations produced by its action upon the alkalies, earths, and metallic oxides would retain their present distinctive appellations. I much doubt however whether chemists in general are as yet prepared for such an innovation; and for my own part I should not easily reconcile myself to the propriety of transferring to the acid constituent a name so long applied to the genus, of which the several salts constitute the species.

This latter objection indeed might be got over, by calling the hydrous acid, in the instance before us, sulphate of water; but such an expedient would compel us to class together bodies, whose physical and chemical properties appear to differ from each other as materially as those of an acid from a neutral salt.

To do this at the present time would be nothing less than to assume the Binary Theory of salts as established on incontrovertible evidence, instead of remaining amongst the debateable points of science, and would therefore be inconsistent with the principle upon which I have proceeded, of recommending no system of nomenclature which implies the adoption of views not generally recognized.

Neutral Salts.—Hence I should prefer that the compounds which are produced by the union of a vegetable acid with a base, or, if you please, by the replacement of the hydrogen in the former by a metal, should still be thrown into the class of *salts*, the *genus* and *species* of each being characterized, as at present, by terms expressive of the acid and base which contribute to its formation.

Vegetable Alkalies.—With respect to these, it will be seen that the bodies so-called may be thrown into one or other of the three classes of amides, imides and nitriles, if these words be any longer retained in the nomenclature of science.

There are indeed bodies called amides which possess acid properties, such as the oxamic acid, which is composed of oxamide $NH^{2} C^{2} O^{2}$ + oxalic acid $C^{2} O^{3}$; but this is nothing more than an instance of a *conjugate acid*, or of a

body which retains its acid properties, when united to another which does not neutralize it. Oxamide, however, and many other so-called ammonia compounds are not *alkalies*, although all alkalies derived from the vegetable kingdom appear to be obtained through the medium of ammonia.

The recent researches, however, of Würtz and Hofmann bid fair to rid us of these three classes of bodies. They have shown, for instance, that many compounds termed amides are nothing more than replacements of one of the hydrogen atoms present in ammonia by various hydrocarbons, and that imides and nitriles are often formed by the substitution, the first of two, the latter of three atoms, of an organic base for the hydrogen of the ammonia.

That the vegetable alkalies, indeed, using the term in its stricter and more ordinary sense, are thus formed, seems now in a manner demonstrated; but before we allow ourselves to substitute the term alkali for the three classes under consideration, it must be shown on the one hand that all organic bodies possessing alkaline properties are formed in this manner, and on the other, that all amides, imides, and nitriles possess alkaline properties.

The existence of *acid-amides* would not in itself militate against this view, as the chemical relations may in them be determined by the acid present, but whether other exceptions may not occur in the way of such a generalization must be left for further inquiries to decide. At any rate it deserves to be considered, whether the bodies of the class known as *Ureas*, a term which has been extended from the animal excretion so designated to other bodies possessed of an analogous composition to it, and therefore to bodies isomeric with the alkaline cyanates, are to be ranked under this same head.

Their analogy of constitution to that of the vegetable alkalies may be seen by comparing the composition of normal urea, as well as of aniline urea, with that of the bodies we have been considering.

Urea is often represented as $C^2 NO, HO + NH^3$; and aniline-urea is shown by Hofmann to have the composition of $C^2 NO\ HO + C^{12} H^7 N$, or of cyanate of aniline.

But the former may be regarded as composed of two atoms of ammonia conjoined, in each of which one atom of hydrogen is replaced by CO, forming as it were a double carbamide, viz.—

$$\left.\begin{array}{l} NH \\ \quad H \\ \quad CO \\ NH \\ \quad H \\ \quad CO \end{array}\right\} = N^2 H^4 C^2 O^2;$$

and in like manner aniline-urea as—

$$\left.\begin{array}{l} NH \\ \quad H \\ \quad C^{12} H^5 \\ NH \\ \quad C^1 O^1 \\ \quad C^1 O^1 \end{array}\right\} = N^2 H^5 C^{14} O^2.$$

But I do not see how the bodies newly discovered by Würtz, consisting respectively of—

Cyanurate of methyl	$C^6 N^3 O^3 + 3C^2 H^3 O$
„ ethyl.........	$C^6 N^3 O^3 + 3C^4 H^5 O$
Cyanate of ethyl	$C^2 N\ O + C^4 H^5 O$
„ methyl.........	$C^2 N\ O + C^2 H^3 O$

can be referred to this same class. They are analogous, indeed, to urea, if this body be regarded as—

Cyanate of ammonia ...... $C^2NO+HO+NH^3$,

but not to the alkaloids, if the latter be represented as replacements of hydrogen atoms by hydrocarbons.

Alcohols.—The term alcohol, although applied to a number of bodies, whose physical properties deviate widely from those of the substance which it was originally meant to signify, is a convenient expression for a class belonging, chemically speaking, to a common type—whether we regard them with Liebig as the hydrated oxides of a hydrocarbon; with Dumas as differing from their respective ethers simply by the addition of a second atom of water; or with Gerhardt as a cluster of atoms, the arrangement of which is unknown to us, but which possess in common the property of being metamorphosed into a carburet of hydrogen, by abandoning the elements of one equivalent of water; and into a monobasic acid, by the substitution of two atoms of oxygen for two of hydrogen.

Although not more than six or seven of such bodies have as yet been discovered, there seems a probability that we may eventually be able to form as many as shall be equal in number to the vegetable acids already recognized, and hence a particular name for the class in general seems indispensable.

Aldehydes.—I am not aware of any objection that applies to the next class—that of aldehydes, which, designating in the first instance the substance prepared by the abstraction of two atoms of hydrogen from wine-alcohol, is intended to stand as a generic term for all bodies similarly constituted.

It ought therefore, as it might seem, to take in the essential oil of bitter almonds $C^{14}H^6O^2$, which by the addition of O^2 is converted into benzoic acid, as well as the analogous compounds derived from salicine, from cinnamile, and from cuminile, each of which gives rise to a corresponding acid.

Thus, essential oil of—

Almonds	$C^{14}H^6O^2+O^2$	produces	Benzoic acid.
Spiræa	$C^{14}H^{12}O^4+O^2$	„	Salicylic acid.
Cinnamon....	$C^{18}H^{16}O^2+O^2$	„	Cinnamic acid.
Cumin	$C^{20}H^{24}O^2+O^2$	„	Cuminic acid.

In none of these cases, however, have the corresponding alcohols been discovered, and hence it will be seen that in Turner's Chemistry they are referred to the class of hydrurets, being considered as compounds of the organic radical, benzoyle $C^{14}H^5O^2$, with 1 of hydrogen. The chemist, however, will have to take his choice of these two views, for he cannot without confusion adopt both; aldehydes in one sense being hydrurets, and hydrurets in another putting in a claim to be regarded as aldehydes.

Ethers.—I next proceed to the class called ethers, a name originally applied to the peculiar volatile fluid produced by the action of sulphuric acid upon wine-alcohol. Here, however, a considerable confusion has been created by placing under the same head bodies connected together by a very vague analogy.

Whether, indeed, we regard sulphuric ether as the oxide, or as the hydrate of a hydrocarbon; or whether, discarding theory, we simply state it as the product of the union of an alcohol with an acid, accompanied by the elimination of the elements of water; it will be found that this generic term has been extended beyond the strict limits of its definition.

Chemists, indeed, in general seem to consider it sufficient to place all those bodies, the basis of which is an ether, under the head of compound ethers;

forgetting, that on the one hand, the greater part of those classed under the latter head differ from the simple ethers, as much as the class of alkalies does from that of neutral salts; and that on the other, bodies of the same composition as the so-called compound ethers, such as the xanthic acid, consisting of two atoms of sulphuret of carbon united to sulphuric ether, $2CS^2+AeO$, are referred by them to a different head—the groundwork of the classification being thus shifted from the composition of the body to its chemical properties.

One is also at a loss to draw a line between a compound ether.. $AeO+x$

and sulphovinic acid.............. .... $\left\{\begin{array}{l}A\ O+x\\ H\ O+x.\end{array}\right.$

Indeed sulphovinic acid, instead of being excluded from the class of ethers, would seem to be the only known body to which the term sulphuric ether can properly be applied.

In short, if the term, compound ether, be retained at all, it should be restricted to bodies like those produced by Williamson, in which a simple ether is united with an ether radical, as the oxide of ethyl with methyl or with amyl, constituting what he calls two and three carbon ethers, according to the number of atoms of carbon present.

I do not cavil with such a mode of distinguishing these several compounds; but as the same nomenclature would be applicable to the simple ethers as well as to those which he describes, it would seem preferable to call them by the name of compound ethers, adding the specific term indicating the number of atoms of carbon present in them, as a method of distinction.

There is likewise another cause of confusion traceable to the use of the term ether for the oxides alike of methyl and amyl, as well as for those of the ethyl series.

Hence, when nitric, carbonic, acetic, benzoic ethers are spoken of, we are left in doubt as to the class meant to be expressed, whether it be an acetate, or other salt, of methyl, of ethyl, or of amyl.

I therefore approve of the method of naming, already practised with regard to certain of these compounds, and would extend the same to all, calling them respectively—

	And in like manner
Chloride of ethyl.	Chloride of methyl.
Bromide of ethyl.	
Nitrate of oxide of ethyl.	Sulphate of oxide of methyl.
Hyponitrate of oxide of ethyl.	Benzoate of oxide of methyl.
Sulphocarburet of oxide of ethyl.	
Acetate of oxide of ethyl.	Acetate of oxide of methyl.

And so with the rest.

Cetone.—This term, improperly, as I conceive, changed to Ketone, has been applied to a class of bodies, formed like acetone by exposing to heat an anhydrous salt of some one of the fatty acids with lime or barytes, such as the acetate, butyrate, benzoate, margarate, or stearate of these bases.

Under such circumstances the acid parts with one atom of carbon and with two of oxygen, which form together an atom of carbonic acid. This combines with the base, whilst the remaining atoms are driven off as acetone in the form of vapour,

$$\begin{array}{rl} C^4\ H^3\ O^3 & \text{acetic acid} \\ \text{leaving } \underline{C^1 \qquad O^2} & \text{carbonic acid} \\ \text{forms } C^3\ H^3\ O^1 & \text{acetone.} \end{array}$$

Mr. Morley has described a product of an analogous kind derived from the distillation of metacetonic or propionic acid, which he calls propione,

$$\begin{array}{rl} & C^6\ H^5\ O^3 \\ \text{leaving} & C^1\ \quad O^2 \\ \hline & C^5\ H^5\ O^1 \text{ propione.} \end{array}$$

Kane indeed has referred acetone to the class of alcohols, regarding it as the hydrated oxide of his hypothetical radical mesytyle; but the mode of its formation keeps it apart from the alcohol series, to which indeed it would be difficult in the present state of our knowledge to refer the other members of this division, so that it would seem advisable that this name should be retained for the entire class of organic compounds which are framed in the manner represented.

Glycerides.—This is another series of organic compounds which deserves our notice, including most of the fixed oils. They are essentially composed of some acid of the description called fatty, and of the oxide of a base called Glycerine.

Although they are in fact neutral salts, yet the peculiarity of their physical characters, and their frequent occurrence throughout both kingdoms of organic nature, appear to render a distinct term for them advisable.

Neutral Bodies.—I do not know that chemical writers have as yet succeeded in establishing any other well-defined groups for the multiform products of the vegetable world, except it be that extensive one consisting of bodies commonly designated as neutral or indifferent, and composed of carbon with a certain number of atoms of water, or at least of oxygen and hydrogen in the proportions that form that fluid.

These in consequence possess much of a common character, and are often convertible one into the other, the differences between them being rather *structural* than *chemical*, and their affinities being less intense than those of bodies which belong to any of the preceding classes.

Part II.

On the Terminations of the Words designating the Members of each Class.

Most chemists have found it convenient to denote bodies which belong to the same class by words terminating alike, although Gerhardt in his classification of organic compounds has neglected this principle, inasmuch as he gives to the general terms indicative of classes the same termination, and moreover places under each head bodies terminating very differently.

Of the terminations commonly understood to designate the members of particular classes, the most unexceptionable perhaps are,—1st, the termination *yle* for the compound radicals, methyle, ethyle, amyle, benzoyle, &c.; and as the above has been assigned to the bodies possessing the atomic constitution assigned to the organic radicals by Liebig, namely $C^2\ H^3$ with the superaddition of two or more multiples of $C^1\ H^1$, it may prevent confusion to adopt the termination *ene* or *en* for those hydrocarbons with an equal number of atoms of carbon and hydrogen which Dumas used to regard as the real organic radicals; thus etherene will be a compound of $C^4\ H^4$, methylene of $C^2\ H^2$, and other compounds with an analogous constitution will terminate in the same manner.

The termination *ine* is reserved for the vegetable alkalies, or for bodies possessing properties of at least an analogous nature.

Thus strychnine, morphine, nicotine, as well as isotine, aniline, and even kreatinine, cholesterine, &c. belong to this group.

It may be doubtful whether kreatine, not being alkaline, is strictly entitled to this termination, and at any rate it should be understood, that it is to be restricted to bodies containing nitrogen; thus the ethers are rightly excluded, because although possessing basic properties, the absence of nitrogen is attended with properties of quite a different nature.

Dr. Hofmann, whose most valuable researches on the nature of the vegetable alkalies have added so much to the number of these bodies, proposes to designate them by terms constructed out of those which signify the hydrocarbons present in each.

Thus Aniline being denoted by NH
H
C^{12} H^5, will be phenylamine;
Ethylaniline .... NH
C^4 H^5
C^{12} H^5, will be ethylophenylamine;
Methylaniline.......... NH
C^2 H^3
C^{12} H^5, will be methylophenylamine;

and when all the three atoms of hydrogen are replaced, we should be compelled to adopt words of the truly formidable length of methylethylophenylamine.

I would suggest to the distinguished author, who amidst the herculean labours of unravelling these intricate combinations, may have wanted time to bestow upon so subordinate a point as their nomenclature, whether his names may not be conveniently abridged by using only the first syllable of that expressive of the organic radicals which replace the hydrogen atoms.

Thus let *meth* stand for methyl,
eth.......... ethyl,
am.......... amyl,
*chl** .... chlorine,
br .... bromine,
nitr .... nitric acid,
phe .... phenyl;

adding in the five former cases to the end the next vowel, when the succeeding syllable begins with a consonant, and in the last the next consonant, when the succeeding syllable begins with a vowel.

In this manner it will rarely happen that the number of syllables of which the word consists can exceed six, as will be seen by the following table:—

Symbol.	*Common Name.*	*Hofmann's Name.*	*Abbreviation proposed.*
$\left.\begin{matrix}H\\H\\C^{12}\ H^5\end{matrix}\right\}N$	Aniline	Phenylamine	Phenamine.
$\left.\begin{matrix}H\\H\\C^{12}\ H^4\\Cl^1\end{matrix}\right\}N$	Chloraniline	Chlorophenylamine	Chlophenamine.

* Some may prefer the abbreviation chlor for chlorine, and brom for bromine. This change however will involve the use of an additional syllable, whenever the next substance expressed begins with a consonant: thus chlophenamine would be chlorophenamine, brophenamine, bromophenamine, &c. The advantage in point of perspicuity will therefore have to be balanced against the inconvenience of increasing still further the length of words, often of necessity extended already to the limits of ready utterance. When however nitrous acid is the replacing body, the introduction of a second syllable to indicate its presence cannot well be avoided, for *ni* alone might stand for several other substances.

Symbol.	*Common Name.*	*Hofmann's Name.*	*Abbreviatio proposed.*
$\left.\begin{matrix} H \\ H \\ C^{12}\ H^{4} \\ Br^{1} \end{matrix}\right\} N$	Bromaniline	Bromophenylamine	Brophenamine.
$\left.\begin{matrix} H \\ H \\ C^{12}\ H^{4} \\ NO^{4} \end{matrix}\right\} N$	Nitraniline	Nitrophenylamine	Nitrophenamine.
$\left.\begin{matrix} H \\ H \\ C^{4}\ H^{5} \end{matrix}\right\} N$	Ethylamine	Ethylammonia	Ethamine.
$\left.\begin{matrix} H \\ C^{4}\ H^{5} \\ C^{12}\ H^{5} \end{matrix}\right\} N$	Ethylaniline	Ethylophenylamine	Ethyphenamine.
$\left.\begin{matrix} H \\ C^{2}\ H^{3} \\ C^{12}\ H^{5} \end{matrix}\right\} N$	Methylaniline	Methylophenylamine	Methyphenamine.
$\left.\begin{matrix} H \\ C^{10}\ H^{11} \\ C^{12}\ H^{5} \end{matrix}\right\} N$	Amylaniline	Amylophenylamine	Amyphenamine.
$\left.\begin{matrix} H \\ C^{4}\ H^{5} \\ C^{12}\ H^{4} \\ Cl^{1} \end{matrix}\right\} N$	Ethylochloraniline	Ethylochlorophenylamine	Ethychlophenamine.
$\left.\begin{matrix} H \\ C^{4}\ H^{5} \\ C^{12}\ H^{4} \\ Br^{1} \end{matrix}\right\} N$	Ethylobromaniline	Ethylobromophenylamine	Ethybrophenamine.
$\left.\begin{matrix} H \\ C^{4}\ H^{5} \\ C^{12}\ H^{4} \\ NO^{4} \end{matrix}\right\} N$	Ethylonitraniline	Ethylonitrophenylamine	Ethyniphenamine.
$\left.\begin{matrix} H \\ C^{4}\ H^{5} \\ C^{4}\ H^{5} \end{matrix}\right\} N$	Diethylamine	Diethylammonia	Diethymine.
$\left.\begin{matrix} C^{4}\ H^{5} \\ C^{4}\ H^{5} \\ C^{12}\ H^{5} \end{matrix}\right\} N$	Diethylaniline	Diethylophenylamine	Diethyphenamine.
$\left.\begin{matrix} C^{2}\ H^{3} \\ C^{4}\ H^{5} \\ C^{12}\ H^{5} \end{matrix}\right\} N$	Methylethylaniline	Methylethylophenylamine	Methethyphenamine.
$\left.\begin{matrix} C^{10}\ H^{11} \\ C^{10}\ H^{11} \\ C^{12}\ H^{5} \end{matrix}\right\} N$	Diamylaniline	Diamylophenylamine	Diamyphenamine.
$\left.\begin{matrix} C^{4}\ H^{5} \\ C^{10}\ H^{11} \\ C^{12}\ H^{5} \end{matrix}\right\} N$	Ethylamylaniline	Ethylamylophenylamine	Ethamyphenamine.
$\left.\begin{matrix} C^{4}\ H^{5} \\ C^{4}\ H^{5} \\ C^{12}\ H^{4} \\ Cl^{1} \end{matrix}\right\} N$	Diethylochloraniline	Diethylochlorophenylamine	Diethychlophenamine.
$\left.\begin{matrix} C^{4}\ H^{5} \\ C^{4}\ H^{5} \\ C^{4}\ H^{5} \end{matrix}\right\} N$	Triethylamine	Triethylammonia	Triethamine.

If we restrict the termination *amine* to the alkalies artificially produced by replacing one or more of the hydrogen atoms of ammonia with a hydrocarbon, and retain that of *ine* for those resulting from natural processes, and

only eliminated by art, we shall mark in this manner the distinction between bodies, which though often isomeric are not identical.

Thus the compound artificially produced, which consists of
$$\begin{array}{l} NH \\ C^2\,H^3 \\ C^{12}\,H^5, \end{array}$$
may be called *methyphenamine*; whilst the principle extracted from oil of tolu, which is found to have the same composition, may retain its name of *toluidine*. The dissimilarity in properties between these isomeric bodies renders a different name for the two indispensable.

Analogy therefore might perhaps lead us to assign to Fownes's artificial alkali, furfurine, the name of furfuramine, although its composition is more complicated than that of Hofmann's alkaloids, as it contains oxygen ($C^{30}\,N^2\,H^{12}\,O^6$).

No such change would be warrantable in the names of bodies, like kreatine, kreatinine, thialdine, &c., which, even if entitled to their present designations, as they contain nitrogen, and the two latter at least possess decided basic properties, bear little resemblance to the vegetable alkaloids, and can neither be referred to the class of amides, according to the old theory, nor yet be resolved into substitutions of hydrocarbons for hydrogen, agreeably to the views of Hofmann.

But how are we to deal with bodies which, like *oxamide*, *bioxamide*, &c., though artificially produced in the same manner as the bodies we have been considering, do not, nevertheless, possess alkaline properties? For them I would propose to retain the received name of amides; only as the distinction between amides, imides and nitriles, seems now to point to an exploded theory, it would be better to extend to them the same principle of nomenclature as that adopted by Dr. Hofmann, namely, that of calling the compound in which 2 atoms of benzoyle are substituted for 2 of hydrogen, not, as Laurent has done, benz*imide*, but dibenz*amide*; and if one were discovered in which 3 atoms were so introduced, to name it tribenz*amide*, and so with the rest.

Mr. Robson, indeed, in a late communication to the Chemical Society, has already pointed out a compound which he terms dibenzoylimide, but this has the composition of $C^{28}\,H^{13}\,NO^2$, or $NH^3 + 2C^{14}\,H^6\,O^2$. It is therefore an ammoniacal compound of benzoyle, and not an amide.

Some chemists have adopted a still more abbreviated form of expression, by attaching the termination *am*, with the name of the combining body prefixed, to indicate such compounds.

Thus benzid*am* has been used to designate aniline; mel*am* for the compound of ammonia with mellon, in the proportion of three of the former to two of the latter. Nothing, however, is gained in point of convenience by adopting the former term, in compensation for the confusion which its use would introduce; for phenamine is as concise a term as benzidam, and certainly more euphonious; but melam belongs altogether to another series, since in it the mellon does not replace the hydrogen atoms of ammonia, but unites with ammonia as such, in the proportion of 2 to 3:—

$$\text{Benzidam, } \begin{array}{l} NH \\ H \\ C^{12}\,H^5 \end{array} \qquad \text{Melam, } \begin{array}{l} \left.\begin{array}{r} NH \\ H \\ H \end{array}\right\} + C^6\,H^4 \\ \left.\begin{array}{r} NH \\ H \\ H \end{array}\right\} + C^6\,H^4 \\ \left.\begin{array}{r} NH \\ H \\ H \end{array}\right\} \end{array}$$

Laurent has proposed to give the termination *se* to those bodies which are formed from a hydrocarbon by the substitution of some element for one or more of the hydrogen atoms present in the original compound. To these letters he prefixes one or other of the vowels, according to the number of atoms so replaced, *a* being used when only 1 atom of the new ingredient is introduced, *e* when 2 atoms, *i* when 3, and so on, till the whole number of vowels is exhausted; after which the series recommences by prefixing the syllable *al* to the vowel.

Thus, from naphthaline, $C^{20} H^{8}$, he derives,—

Chlornaphthase $C^{2} H^{7} Cl$,
Chlornaphthese $C^{2} H^{6} C^{2}$,
Chlornaphthise $C^{2} H^{5} C^{3}$, and so on; but
Chlornaphthalese is $C^{2} H^{2} Cl^{6}$.

Other refinements upon this mode of nomenclature are proposed in M. Laurent's various papers, and well deserve the attention of those who follow up similar tracks of research.

The termination *al* has been appropriated to combinations into which aldehyde enters as a constituent, or which are derived from that body. It may be right, however, to point out, that many substances bound together by a very loose analogy are thus embraced.

Thus chlor*al* is aldehyde in which the 3 hydrogen atoms are replaced by 3 of chlorine. $C^{4} H^{3} O + HO$ becomes $C^{4} Cl^{3} O + HO$.

Acet*al*, on the contrary, is aldehyde united with oxide of ethyl.

$$\begin{array}{ll} C^{4} H^{3} O^{1} & \text{aldehyde} \\ C^{4} H^{5} O^{1} & \text{oxide of ethyl} \\ \underline{\quad H^{1} O^{1}} & \text{water} \\ C^{8} H^{9} O^{3} & \text{acetal} \end{array}$$

whilst the analogous compound of aldehyde with ammonia is called simply aldehydammonia.

The term *ethane*, in like manner, comprises compounds of which ether forms a part; but it should be confined to those into which an acid does not enter as a constituent, since in the latter cases the nomenclature of the salts may be preferable.

Thus *urethane* may be retained as the name for a compound of urea and carbonic ether, or the carbonate of oxide of ethyl, its composition being—

$$\begin{array}{ll} \text{Urea} \ldots\ldots\ldots\ldots & C^{2} H^{4} O^{2} N^{2} \\ 2 \text{ Carbonic ether} \ldots & \underline{C^{10} H^{10} O^{6} \quad\;} \\ & C^{12} H^{14} O^{8} N^{2} \end{array}$$

But it would seem better to designate the substance called oxamethane, by the term oxamate of oxide of ethyl—

$$\begin{array}{ll} \text{Oxamic acid} \ldots & C^{4} H^{2} N^{1} O^{5} \\ \text{Ether} \ldots\ldots & \underline{C^{4} H^{5} \quad\; O^{1}} \\ & C^{8} H^{7} N^{1} O^{6} \end{array}$$

and oxamethylane by that of the oxamate of oxide of methyl.

In this manner we shall also avoid the confusion that may arise between names so related as oxamethylane and oxamethane, the former indicating the oxamate of methyle, the latter that of ethyle.

I am unable to attach any definite meaning to the termination *an*, by which certain organic compounds connected with urea are now designated.

Alloxan, one of them, is regarded as an acid, the erythric of Brugnatelli. Murexan may probably be a salt of cyanoxalic acid and ammonia; but not-

withstanding the researches of Liebig and Wöhler, the true relations of their bodies one to the other still appear obscure.

The termination *one* appropriately denotes bodies formed from vegetable acids by the abstraction of 1 atom of carbonic acid, and should be reserved for this same description of bodies; but the use of the analogous termination *ole* for those formed by the abstraction of 2 atoms of carbonic acid from the same may be apt to cause some ambiguity. Thus we use the terms benz*ole*, phen*ole*, and anis*ole*, as being derived respectively from the benzoic, salicylic, and anisic acids.

Benzole....	$C^{12} H^6 + C^2 O^4$	forming	benzoic	acid	$C^{14} H^6 O^4$.
Phenole ...	$C^{12} H^6 O^2 + C^2 O^4$	,,	salicylic	,,	$C^{14} H^6 O^6$.
Anisole....	$C^{14} H^8 O^2 + C^2 O^4$	,,	anisic	,,	$C^{16} H^8 O^6$.

But unfortunately the same termination, or one so similar as to be easily confounded with it, has been applied to bodies of an entirely different composition, in order to indicate that they belong to the class of oils. Thus benzoil*ol* is the name given by some to the essential oil of bitter almonds; cinnam*ol* to the oil of cinnamons, and so with the rest.

It would seem better that these latter names should be abandoned, and that the termination *ole* should be applied only to bodies formed in the same manner as benzole and its analogues.

The above remarks and suggestions in relation to the classification and nomenclature of organic compounds, crude as they may appear in the eyes of chemists more thoroughly versed in the subject than myself, will not be altogether thrown away, if they only serve to stimulate others to make it the subject of their consideration, and thus lead to the establishment of more precise and convenient terms of art. Some indeed may object that the whole of this department of chemistry is at present in a transition state, and consequently that no fixed rules, for classifying or naming the various products that present themselves to us whilst investigating it, can as yet be laid down. But the fact is, that we are compelled, whether we will or no, by the very necessity of the case, to adopt a certain system of nomenclature whenever a new body comes before us, and the only question is, whether this system shall be consistent with itself, and shall convey a correct impression of the relation in which, at the time of its discovery, we suppose the body to stand with reference to others.

It has been my endeavour, in the preceding remarks, to point out what appear to me to be the views which have guided the most eminent chemical authorities in the names they have thought proper to impose, and thus rather to give expression to their ideas, than to advance any theories or methods of my own invention.

I would however submit to the chemists here assembled, whether the want of precision which has been shown to exist in the application of those principles of nomenclature to particular cases, does not suggest the expediency of having the whole subject brought under revision by this Section, or by a Committee appointed by it, and of having certain definite rules laid down by their joint authority, in conformity with the usage, and in accordance with the understood principles, of those great masters of chemical science to whom we all look up in deference.

In the mean time, I will, in conclusion, submit to the Section the few following directions, as calculated, in my humble opinion, to simplify the nomenclature of organic compounds, and therefore as worthy of adoption, at least provisionally, in order to render it more expressive and perspicuous.

1st. That in the case of bodies only known to be produced by artificial

processes, names should, if possible, be given them by putting together terms expressive of the several constituents which contribute to form them; but as no name ought, for the sake of convenience, to exceed in length six or seven syllables, the first syllable only of the word indicating each component part should be introduced into that of the compound designated.

This principle I have endeavoured to carry out, in the modifications proposed for the names given by Hofmann to the various substances, produced by him through the replacement of atoms of hydrogen by hydrocarbons. The necessity for such abbreviations will, I conceive, be the more felt, now that in the further prosecution of his researches no less than 4 atoms of hydrogen have been so replaced*.

2nd. When, owing to the complicated nature of the body discovered, or to the obscurity that hangs over its real nature, it seems impracticable to name it on the plan above proposed, a word expressive of some obvious and marked physical or chemical character should be selected, and one whose Greek or Latin root may be readily apprehended.

* I must confess myself quite unable to invent pronounceable names for such compounds, if it be ruled, that they are to express, not merely the nature of the constituents, but likewise the origin or mode of formation attributed to each.

Provided the latter condition be waved, I do not despair of assigning to them terms little more difficult to articulate than those proposed for the bodies described in Dr. Hofmann's preceding papers. Should the alterations suggested be regarded as sinning against any understood Canons of Nomenclature, I see no alternative, but that of discarding names for these new bodies altogether, and contenting ourselves with symbols; for a word which cannot be uttered, whilst it is in no respect preferable to a symbol, is much less easily written; and such I apprehend to be the case with some of the terms which I have given below, and for which therefore, I venture to propose the annexed substitutes:—

Symbol.	*Hofmann's Names.*	*Names suggested.*
$\left.\begin{array}{l}C^4\,H^5\\C^4\,H^5\\C^4\,H^5\\C^{12}\,H^5\end{array}\right\}$ NO, HO...	Oxide of Triethylophenylammonium	Oxide of Triethyphenine.
$\left.\begin{array}{l}C^2\,H^3\\C^4\,H^5\\C^{10}\,H^{11}\\C^{12}\,H^5\end{array}\right\}$ NO, HO...	Oxide of Methylethylamylophenylammonium ...	Oxide of Methamyphenine.
$\left.\begin{array}{l}C^4\,H^5\\C^4\,H^5\\C^4\,H^5\\C^4\,H^5\end{array}\right\}$ NO, HO...	Oxide of Tetrethylammonium	Oxide of Tetrethine.
$\left.\begin{array}{l}C^4\,H^5\\C^4\,H^5\\C^4\,H^5\\C^{10}\,H^{11}\end{array}\right\}$ NO, HO...	Oxide of Triethylammonium	Oxide of Triethine.
$\left.\begin{array}{l}C^4\,H^5\\C^4\,H^5\\C^4\,H^5\\C^2\,H^3\end{array}\right\}$ NO, HO...	Oxide of Triethylomethylammonium	Oxide of Triethemethine.
$\left.\begin{array}{l}C^2\,H^3\\C^4\,H^{15}\\C^4\,H^1\\C^{10}\,H^5.\end{array}\right\}$ NO, HO...	Oxide of Diethylomethylamylammonium...	Oxide of Diethemethamine.
$\left.\begin{array}{l}C^2\,H^3\\C^2\,H^3\\C^2\,H^3\\C^2\,H^3\end{array}\right\}$ NO, HO...	Oxide of Tetramethylammonium...........	Oxide of Tetramethine.
$\left.\begin{array}{l}C^{10}\,H^{11}\\C^{10}\,H^{11}\\C^{10}\,H^{11}\\C^{10}\,H^{11}\end{array}\right\}$ NO, HO...	Oxide of Tetramylammonium	Oxide of Tetramine.

Thus mercaptan, kapnomor, pittacal, parabanic acid, allophanic ether, seem for the above reasons objectionable; whilst such terms as mellon, creosote, glycerine, &c., are perhaps as good as could have been fixed upon under the circumstances for the bodies so designated.

3rd. That when the substance to be named has been produced by natural processes, and only eliminated by art, a name expressive of its origin would seem preferable to one taken from its composition.

Hence not only should the terms strychnine, nicotine, &c. be retained, but even toluidine, xylidine, and cumidine, although apparently produced by the replacement of hydrogen atoms, like the artificial compounds which Hofmann has discovered, should be preferred to words indicative of their component parts.

4th. That in general bodies belonging to the same class, or formed according to the same type, should preserve the same termination; but that nevertheless when a body, long recognized and familiarly known to us, has been shown to belong to a type to which a particular termination is assigned, it may not be advisable to alter its recognized and received appellation, so as to bring it into harmony with the rest.

Thus the term urea should be retained unaltered, notwithstanding its analogy in certain respects to the organic alkalies, which have the termination *ine* appropriated to them.

On two unsolved Problems in Indo-German Philology.

By the Rev. J. W. Donaldson, *D.D.*

The science of Ethnography, which involves the arrangement and classification of the different members of the human family, and explains their common origin and casual juxtapositions, must be regarded as the most important accession to systematic knowledge which has been made in our time. It is only recently that it has found a place among the subjects of inquiry suggested to the British Association; and until the present year it has been entrusted to a subsection only. But if we estimate its value properly, and consider the diversified range of study which it implies, and the vast number of labourers who are contributing in different ways to lay the foundations of this great edifice, we may fairly plead for a recognition of its right to a foremost place among those sciences which it is the design of this Association to advance. At any rate there is no branch of study which is more likely to profit by the retrospective surveys, for which an annual meeting like the present furnishes so good an opportunity. For while no science is more steadily progressive than ethnography, and while none more rapidly accumulates the materials of induction, its encyclopedic range, and the want of communication between the many active minds engaged upon it, especially necessitate a periodical report of its existing state, such as may suffice to indicate what has been really effected, and to point out the objects to which the attention of inquirers may still be most profitably directed. At the present season, when the Great Exhibition in the metropolis has brought to our shores deputations from all the leading families of the Indo-European race, and when we are met near the East-Anglian coast, where Britain received the first instalments of that northern colony which gave a new name to our island and ingrafted on our language its most characteristic elements, it seems particularly incumbent upon us to look back on what has been

secured in the scientific classification of the race to which we belong, and to indicate the outlying difficulties which invite the united efforts of modern genius and learning.

Those who have fully studied the subject will readily admit that the great majority of questions raised by the various writers on Indo-Germanic ethnography have received satisfactory answers, and that our general results rest on the solid basis of scientific certainty. There are, in fact, only two problems suggested by this subject which still demand an adequate solution—the amount and nature of the affinity which connects the Indo-Germanic and Semitic branches of the human family, and the origin and interpretation of the ancient Etruscan language. The difficulties occasioned by the Basque or Euskarian language may be considered as having received at least an approximate settlement, and it may be concluded generally that this isolated idiom is due to a combination of the Celtic and Finnish elements, which form, either separately or together, the outer fringe or hem of the population of Europe. But the other two problems still require a scientific investigation. Indeed it may be considered as the greatest reproach to modern scholarship that the Etruscan language is little better known to us than it was to Dempster; and that while we can read the Cartouches of the Pharaohs, and interpret the cuneiform records of Darius, we cannot come to any satisfactory result respecting a language which was spoken by the immediate ancestors of Mæcenas, and which, long after the time of Pericles, was the vernacular idiom of one of the most powerful and civilized of the nations of antiquity. And with regard to the Semitic question, it is scarcely less strange that we should still allow Rabbis and Talmudists to separate the language of the Jews from that of the Greeks by a Chinese wall of demarcation, and that the two adjacent sources, from which the streams of European civilization flowed until they converged in one united channel of religious philosophy, should still be referred to different hemispheres, and should be thought to present indisputable marks of a diversity of origin.

Having approached the discussion of these topics on various occasions, and having surveyed them from different points of view, but always with a tendency to the same result, I have thought that my best contribution to this Meeting would be such a general statement of the conclusions at which I have arrived as might tend to facilitate a mutual understanding between myself and others who have not yet developed the direction of their researches in the same field. For it appears to me to be one of the most important of the objects of this Association to promote the intercourse of those who cultivate science, and thus to substitute a systematic division of labour for that purposeless repetition of the same exertions, which is the natural consequence of unconnected inquiries.

I have been led to include the two unsolved problems in Indo-Germanic ethnography under one head, because I believe that one and the same channel of investigation will conduct us to the proper issue in each case. The scientific procedure, according to my view of the matter, will show that the solution of both difficulties depends on a satisfactory definition of the Asiatic starting-point and European limits of the Sclavonian emigration. And I shall endeavour to show you that the first and last contacts of this great family of men,—the extreme edges of this great stratum of population,—furnish us with the points of transition to the Syro-Arabian stock in general, and to the Etruscan nation in particular.

But I must begin with some principles of universal application, which appear to me to be the axioms or postulates in every ethnological argument, but which, I fear, are not sufficiently regarded as such. As the sum of our

knowledge hitherto acquired tends to confirm our instinctive belief and almost universal tradition respecting the unity of the human race, it seems reasonable to start with the assumption that men cannot be divided into zoological genera; and as every presumption is in favour of this axiom, we must leave the *onus probandi*, with regard to any other hypothesis, upon those who feel disposed to contradict us. For my own part, I confess I feel somewhat indignant when I fall in with an attempt to classify men according to the external peculiarities of feature and colour. I consider it a degrading theory to maintain that man belongs to the merely animal kingdom at all; and if in other departments of their own science naturalists would refuse to place in the same group, whether zoological or phytological, species which were not connected together by at least three marks of essential affinity, affecting their absolute definition, I cannot understand why man, the only reasoning and thinking being, should be placed by the side of those creatures, which cannot reason or speak, merely on the strength of an outward analogy, which does not in the slightest degree affect our distinctive attributes. Scientific ethnology seems to me to start from the postulate that our race is essentially one, and accidentally different. In many cases, we can clearly trace the causation of these differences to the influence of climate, aliment, and civilization, and as they do not, in the widest and most pronounced form of discrepancy, interfere with the definition of man, as such, it is surely unscientific to make ethnography dependent in any way on the casualties of physical conformation. Speaking with reference to the whole period of time which must have elapsed since the establishment of our species on the surface of this planet, we may say that the settlement of the Anglo-Saxons in North America is an event of yesterday, and yet they already begin to exhibit physical characteristics more akin to those of their neighbours than to those of their ancestors. Peculiarities affecting the cellular substance and maxillary process may place an almost Turanian stamp on a highly cultivated United States man, who can discourse eloquently in the language of Shakspeare, who bears an English name, and exhibits in all his actions the energy of that race which has spread its colonies over the whole world. Differences of craniological structure and intellectual development must also be regarded as accidents perfectly consistent, not only with the aboriginal unity, but also with the present identity of men. May not the same family contain an idiot and a philosopher? Does not every family exhibit the gradation of helpless infant, thoughtless boy, and mature man? It is surely idle to endeavour to classify the human race by distinctions which may be found in the same household. The latest book* which has treated "the varieties of man" as a branch of "natural history," arranges the population of the world under three great subdivisions: the *Mongolidæ*, corresponding mainly to the Turanians; the *Atlantidæ*, including the Semitic race; and the *Japetidæ*, who are identical with the Indo-Europeans. Now almost any man's experience may convince him that hereditary civilization and similar opportunities will place Jews and Gentiles, Mongolians and Indo-Germans, on a footing of the most perfect equality. The Atlantid Toussaint was a match for his Japhetic antagonists; the Mongolian Kossuth has held his own in European statesmanship; and on the battle-field of Austerlitz the same military talents were displayed by Miloradowitch, who was a Servian and therefore of the purest Indo-German stock, by Bagration, who was a Georgian prince, and therefore of Mongol extraction, and by Soult, who, according to D'Israeli, derived his origin from the Semitic Jews.

As then a difference of climate and aliment is calculated to produce, in

* Dr. Latham's.

the same race and within a limited time, striking bodily distinctions, and as, on the contrary, similarity of culture and habits seems to cause, in different races, an identity of craniological structure and intellectual development, it is clear that ethnography, as the science which treats of the different families into which mankind are divided, and accounts for their distribution over the surface of the globe, cannot be satisfied with the results of physiological investigation. The comparative anatomy of the different races of men is not at all calculated to explain the facts of our science or to assist us in forming our classification. Interesting on its own account, as an important branch of pathology, it is useful to the ethnographer only as removing the difficulties by which he would otherwise be encumbered. It is our proper business to show why a nation or people, having its own peculiar modification of language, came to be settled in a particular locality, and in what manner it is related to the contiguous tribes. Now it is obvious that there can be but four elements in such an inquiry as this. (1.) Our first and most important step is to examine philologically the language of the tribe; (2.) the ancient designation of the people, and the names of persons and places within the district, furnish us with additional materials of the same kind; (3.) the knowledge thus acquired is to be compared with any historical traditions which may be available; and (4.) the final test is supplied by physical or descriptive geography. To take a simple and easy example: the district called Hungary is mainly occupied by the Magyars, who are distinguished by their language from the German, Sclavonian and Wallachian tribes with which they are intermixed. It is by their language that we perceive their ethnical identity with the Laplanders of the North and with the Bashkirs of the South. The names of their nobles, of their cities, and of their rivers and plains, show to what an extent they have superseded or yielded to conterminous influences. Their history gives a distinct account of their immigration, and the geographical conformation of the country which they occupy shows how they originally entered it by the outlet of the Danube, and how their ulterior development was controlled by natural obstacles. The same process might be applied in every case; and thus, while the facts are established by a philological investigation of the language spoken and of the names imposed, these facts are explained and accounted for by the results of our historical and geographical knowledge. If we desire to ascertain the origin of any branch of the great human family, this is the only course which we can pursue, and if we have access to all four sources of information, the result is safe and satisfactory. It rarely happens that any further light is derived from the observation of physical peculiarities. Except as an evidence of hereditary descent, within narrow limits and without the operation of climatologic peculiarities, an appeal to physiology is superfluous. If ethnography can solve the problems which it undertakes, it must do so without the aid of the anatomist, and we should only complicate our difficulties, if we allowed the precarious and casual to take the place of that which is a proper and essential element in our inquiries.

Under these circumstances, we cannot too soon relinquish, as unscientific, the attempt to classify mankind by the accidents of physical conformation. Differences of race are not regulated or explained by differences in the parietal diameter of the cranium, or in the maxillary process, or in the pelvis, any more than by varieties in the colour of the hair and skin. To separate men into different groups according to their outward distinctions, which do not affect the essential characteristics of our race, is not less puerile than the *primâ facie* classification, which gives rise to the earliest nomenclature in the

natural history of lower animals. There some one prominent quality is grasped by the mind, and an attributive noun is formed, which, so far from defining the species, is often equally applicable to animals of the most different genera. We smile when we are told that the *fox*, the *stoat*, and the *lobster*, are designated in Old English by a common name referring to the wideness of the tail. But surely this is only the same process as that which induces us to distinguish the human race into great families by a reference to external characteristics, many of which may be exhibited by the different members of the same family, and all of which may exist, at least in approximate forms, in members of the same national tribe. Scientific classification ought to be regulated by the most advanced results of our knowledge, and not by the vague impressions resulting from our first cursory observations. Imperfect science, like imperfect manhood, dwells upon differences long before it can perceive resemblances. It is the business of the matured intellect to find the common element by which classes are linked together, and to subordinate the multiform exterior to the unity which reigns within. If this is true in all cases, it is so especially when we have to do with man, whose essential definition is independent of his external frame. The instinct which convinces us that our race constitutes one family, dispersed indeed by emigration, but connected with one home by a common pedigree, is confirmed by all accessible knowledge, and it seems that no ethnographical classification can be permanently satisfactory, unless it recognises this primeval unity, and contrasts it with the subsequent process of separation and dispersion. As the evidences furnished by language, tradition, and physical geography all point to Armenia as the first cradle of the human race, it would seem to be most scientific to contrast the original nucleus, which formed itself in this region, and more gradually expanded itself in massive outpourings, with the scattered offshoots which were always dispersing themselves in scanty streams of restless wanderers. We shall thus find two great subdivisions of the population of the world—the *central* and the *sporadic*. The former will include the *Indo-Germanic* race, which extended itself from Irân to India on the one side, and on the other side peopled the whole of Europe: and the *Semitic* race, which after having reached the highest pitch of civilization in Syria and Egypt, pushed forward its undulations of decreasing intelligence until it had covered the whole of Africa. All the rest of the world, the north and east of Asia, America, and the intervening islands are peopled by branches of the sporadic race, more or less connected with the Eastern or Iranian group. Among the various advantages of this classification, I may mention that it not only represents the present results and obvious tendencies of our researches, but is also conformable to our daily experience. For the world is still but partially peopled, and still exhibits itself as a central mass, sending forth sporadic ramifications of colonies. And even if we were to discover reasons, much more convincing than any which have as yet been produced, in favour of the Polyadamism of our race, nothing can alter the fact that there has been a centre and starting-point of human civilization, and that the cradle of the Semitic and Indo-Germanic families has sent forth those tribes, whose history is that of the world.

However, it is not my purpose on the present occasion to pursue these general reasonings any farther. I may be content to refer to what I have elsewhere written on the subject. And I shall proceed at once to my immediate object, namely, to the indications of the important conclusions deducible from a more accurate survey of the first and last contacts of the Sclavonians.

It can scarcely be necessary to trouble this Association with prolix details respecting the Indo-Germanic family. For the sake of method and clearness, however, I must recapitulate the main facts of the case.

The district called *Irân*, which we must regard with filial respect as the birthplace of our race, and with lively political interest as the western limit of our eastern empire, may be defined generally as the plateau which is bounded by the sea on the south, and by the Tigris, the Oxus, and the Indus on the other three sides. These great rivers are however only a part of the fences by which it is enclosed on the land side. On the north the Caspian and Aral seas, together with long ridges of mountains, the offshoots of the Himâlayas, form a cordon more or less difficult of transit. And to the east, more than one rocky range, now advancing to the Indus, now receding from it, and penetrated only by passes white with the bones of slaughtered armies, stand fast as a natural wall not easily surmounted by those who would sally forth from the Sindian plains.

Within these limits sprang up, side by side, the different members of that great Iranian or Indo-German race, with the subdivisions of which I am now concerned. One band after another of hardy and enterprising emigrants escaped from the comparatively narrow limits of this plateau, and carried their high courage and intellectual capabilities to be strengthened and increased under the bracing influences of the climate of Europe. Among themselves and within the limits of Irân they were known by different names, just as brothers are distinguished from brothers; they had also marked distinctions of moral and speculative qualities, just as the children of one parent may differ from one another in these respects. According to their different characteristics were their different destinies, which they have all fulfilled according to the original pattern.

Omitting the desert interior of the Irânian plateau, we may divide its ancient population into the four following groups: the *Persians* or *Germanians* who abutted on the Persian Gulf and Sea and looked towards Arabia; the *Medes* or *Matians*, who extended from the Caspian until they reached the Persian borders; the *Sacæ*, who extended from Khorassan to Bokhara; and the *Arians*, who spread themselves from Hinduh-kuh over the mountains which look down upon the Indus and its tributaries. It is the consistent result of all ethnographic speculations that the conquerors of the Punjab and Hindostan, to whom we owe the Pali and Sanscrit languages, belonged to this last branch of the Iranian stock; and it is equally clear that the distinctive elements of the population of Europe are traceable to the other three branches.

The Turanian and Celtic races, to whom we undoubtedly owe the first beginnings of the population of Europe, have been extruded to the uttermost parts of the continent, and are so overruled by and intermixed with subsequent importations of ethnical ingredients, that they may be and usually are omitted in a general survey of the Indo-Germanic race. Indeed, if we except the comparatively modern settlements of the Ugro-Tatarians in Hungary, and of the Turco-Tatarians in Macedonia and Greece, we must divide the whole population of Europe into three and only three classes—the *Sclavonians*, whom we will call A; the *Low-Germans*, *Goths* or *Saxons*, B; and the *High-Germans*, or *Herminones*, C. Of these it is clear that class A entered Europe first, and that throughout the greater part of the district where it is now found, it escaped all mixture with the subsequent bands of emigrants from Irân. In ancient Greece and Italy the fusion in different proportions of A+C and A+B gave rise to the Pelasgo-Hellenic and Pelasgo-Umbrian races, and a similar mixture of A+B in the north of Europe

constituted the Lithuanian people. Among the Teutonic tribes there are frequent compounds of B and C, but the Scandinavian tribes exhibit the Low-Germans, or class B, in the purest form. It is the intention of the following pages to use the distinction between the Scandinavian and pure Sclavonian languages for the purpose of resolving into its separate elements the Italian compound of the two which has caused so much difficulty to philologers. But in the first place I must consider the Asiatic contacts of the Sclavonian race, and the problem, which is suggested and solved by these juxtapositions.

Schafarik has shown that the earliest names under which the Sclavonian race is recognised in Europe are the appellation of *Wends*, *Winden*, O.-H.-G. *Winidâ*, A.-S. *Veonodas*, which was given to them by their German neighbours, and the title of *Servians*, *Serbs*, *Sorbs*, which they bestowed upon themselves. It is of no avail for the purposes of ethnography to examine the name which this race received from their neighbours, but it is interesting to inquire why they called themselves *Servians*. From a comparison of the forms *Sermende*, *Sirmien*, with others in which the *b* is changed into *m*, Grimm (*Gesch. d. deutschen Sprache*, p. 172) is disposed to recognise the root *Serb-* in the name of the ancient *Sarmatians*. I consider this latter word as a compound, and shall discuss its meaning by and by. Schafarik, who does not now admit the Sclavonian affinities of the Sarmatians (*Slawische Alterthümer*, i. p. 333, *seq*. ed. Wuttke), connects the ethnic name *Servian* with the Russ. *paserb* = *puer*, *privignus*, Pol. *pasierb*, which he identifies with *pastorek*, *pasterka* = *privignus*, the *t* in the latter being an arbitrary insertion, as in *strjbro* for *srebro* = *argentum*, &c., so that *pa-ser-b* and *pa-ser-k* differ only in the formative affix, and the two words fall into an equality with one another and with the Sanscr. *paser* = *puer*, Pers. *puser*, Pehlevi *poser*, &c. The root then is that of the Sanscr. *sû* = *generare*, and the meaning of the ethnical name *Serb* is merely "*natio*, *gens*," after the analogy of the term *Deutsch*, *Thiotisk*, derived from the Gothic *thiôda* = *gens* (*Slaw. Alterth.* i. p. 178–180). This appears to me very vague etymology, and I have no hesitation in proposing another derivation, which, though it ultimately falls back on the same root, presents it under a special form and not in a monosyllable, which, as Grimm says, might be the mother of every word beginning with the letter *s*. The old gloss of the *Mater Verborum*, published by Schafarik and Palacky, in *Die ältesten Denkmäler der Böhmischen Sprache*, contains the following definition, p. 225 [303]: "*Sr'bi*, Sarmate *sirbi* tum dicti a *serendo* i. quasi *sirbntm*." Now the earliest notice which we have respecting the Sclavonians is the statement of Procopius (*B. Goth.* iii. c. 14. p. 498) that their ancient name was Σπόροι, which he refers to the fact that they were σποράδην διεσκηνημένοι. We cannot doubt that Σπόρος involves a metathesis of the genuine *Serb* or *Sorb*, and it is equally obvious that this metathesis was occasioned by a wish to make the word correspond in Greek to the meaning which Procopius had heard attached to it. But there is no reason whatever for supposing that the metaphor, involved in the Greek adverb and in the name of the scattered islands of the Ægean, was also common in the old Sclavonian idiom. On the contrary, the analogy of other Sclavonian gentile names would show that the word would designate them by their employment, or by the physical features of the locality, and that they might be called "sowers," *i.e.* "agriculturists," as occupiers of the plains, in contrast to their neighbours, just as the *Chorwats* got this name from being mountaineers, and just as the *Pomeranians* were so called from living on the sea. Thus the name *Serb* will correspond in effect to that of *Pole*, the latter denoting the plains in which the agriculturists were settled,

and the former indicating their usual occupation. The name *Sclavonian*, *Slow-jane*, *Slow-jene*, has generally been derived, either from *slawa*, 'glory,' and so considered as synonymous with *slawetnj = gloriosi, laudabiles, celebres*, or else from *slowo*, 'a word,' in which case it would signify the ὁμόγλωττοι, *Sermonales*, articulately-speaking natives, as opposed to the *Nemj*, *Nemci*, 'dumb,' βάρβαροι, or unintelligible foreigners. Instead of these complimentary derivations, Schafarik now proposes (*Slaw. Alterth.* ii. p. 42 foll.) to consider the word as a local title, like the other words in *-ane* or *-ene*, and would rather derive it from the geographical name *Slowy*, which he would connect with *sallawa*, 'an island,' 'meadow,' or 'holm,' so that the *Slowjanin* would be the 'islanders,' with reference perhaps to the marshes which surrounded their original settlements. A comparison of *srebro* with *silver* might even suggest the possibility of identifying the roots *serb* and *slaw*. At any rate it is clear that when the wars of the ninth and tenth centuries furnished an abundance of Sclavonians as prisoners and captives, the German names for these unhappy persons were indifferently *Slave* and *Syrf*, a circumstance which indicates a widely-spread identity of ethnical designation.

That the ancient *Sauromatæ* or Sarmatians were ethnologically identical with the Sclavonians appears to me to be certain. The grounds on which Schafarik has maintained the contrary opinion do not amount to a valid argument. It is quite possible that the ancients may have used the term *Sarmatian* in a lax and vague manner, and may have classed with the Sclavonian tribes, to whom this name belonged, some others which were more or less connected with different branches of the Indo-German family. For example, the title seems to have included the Lithuanians, who were Sclavonized Low-Germans belonging to the great stock of the Getæ. In the same way, the term *Scythian* is extended so as to include, not only the Sarmatian tribes, but also others of Gothic and Turanian origin. It is quite clear, indeed it is generally admitted, that the Sarmatians, as such, were Sclavonians, and, as Grimm has observed (*Gesch. d. deutschen Spr.* p. 173), if the Sarmatian word ζίρις, given by Lucian in his *Toxaris* (40), can be shown to be Sclavonian, this alone would settle the point. Schafarik himself admits (p. 370), that many of the Sarmatian proper names betray a Sclavonian origin. The question is one of considerable importance; for if the universal belief, that the Sclavonians and Sarmatians are identical, be allowed to hold its ground, we can trace the Sclavonian migration from Irân through all its stages, until we get back to the original starting-point. Every authority concurs in assigning a Median origin to the *Sauromatæ*, and according to Gatterer's etymology, which is generally received, the name itself signifies "the Northern *Mateni* or Medes." One of their tribes was called *Ixa-matæ* or *Iaxa-matæ*, *i.e.* "Medes from the Iaxartes or Oxus." And thus we can lay down the route of the Sclavonian population from the borders of Assyria through Media and Hyrcania, round the eastern shores of the Caspian and Aral seas, across the Tanais, and so on, until we find them extending from the Baltic to the Adriatic.

Now if we can identify the Sclavonians with that branch of the great Iranian family which occupied Media, it will follow that their language, in its oldest form, must furnish the point of contact between the Indo-Germanic and Semitic idioms. And I proceed to indicate some of the important inferences which may be drawn from the comparison thus suggested.

The researches of Col. Rawlinson may be regarded as supplying us with at least *primâ facie* evidence of the fact that the language of the ancient Assyrians and Babylonians was in the same syntactical or disintegrated condition as the Hebrew and other Semitic dialects. He seems to have recog-

nised a definite article, prepositional determinatives of the oblique cases, personal pronouns prefixed rather than affixed to the verb-form, and even the peculiar modifications which are generally known as conjugational varieties of the Semitic verb. On the other hand, it has long been an opinion maintained by ancient orientalists that the *Chaldæans, Kasdîm*, or *Kurds*, were an Indo-German tribe who descended from their mountains and conquered the plains of Mesopotamia about the time of the Prophet Isaiah. Michaelis and Reinhold Forster have gone so far as to claim for them a Sclavonian affinity, and Gesenius, who rejects this hypothesis, still connects them with the Medo-Persians. But if they were of the Median stock, they were also Sarmatian or Sclavonians. And thus, starting from two opposite points of view, we come to the same conclusion, and find the Indo-Germans and Semites in close contact, if not intermingled with one another, on the banks of the Tigris. Every step which we take in the way of induction confirms our *à-priori* reasoning, and the internal evidences of language enable us to arrive at a demonstrative result.

The distinctive characteristics of the Semitic languages may be said to consist in the generally triliteral form of their uninflected words, and in the invariably syntactical contrivances by which the whole mechanism of speech is carried on. I seek the cause of this in the early adoption of alphabetical writing, in the establishment of a literature, and in the unusually frequent intermixture of cognate races. The distinctive characteristics of the Sclavonian languages, as they appear in Europe, may be said to consist in the perfection of the etymological forms and in the total absence of merely syntactical contrivances, and the cause of these peculiarities may be sought in the known fact that they have been more free than any other branch of the Indo-Germanic family from intermixture or fusion, and that their literature is of more recent origin than that of any great section of the human race. Thus we may say, that the Sclavonian and Semitic tongues stand in direct antithesis or contrast, as far as their state or condition is concerned. And if, in spite of this, they still retain marks of their original contact, we must admit that the argument from internal evidence is the strongest possible, because it is obtained under the most unfavourable circumstances.

Now the facts, on which I rely as conclusive, are these:—(1.) that there are verbal coincidences between the Sclavonic and Semitic languages which cannot be accidental, which are not traceable to any subsequent intercourse between the two races, and which are not common to the Sclavonic and other Indo-Germanic idioms; (2.) that the Sclavonian language alone furnishes parallels to the Semitic conjugations, and presents words in such a state of agglutination as would be liable to the triliteral pollarding from which the existing system of Semitic articulation seems to have sprung.

(1.) There is no word more peculiar to the Semitic languages than the expression for goodness and convenience, which in Hebrew is טוֹב, *dhôb*, in Arabic دبر *debr*. I have remarked elsewhere that the articulation of the Hebrew ט must be a *medial* rather than a *tenuis* aspirated, and the Arabic synonym shows that it is so in this particular case. Now this root, which does not occur in any other Indo-Germanic language, is as common in Sclavonic as in Hebrew, and, what is remarkable, it constantly occurs with the affix *r*, which it exhibits in Arabic. Thus we have in Polish *dob*, "a suitable time," *dob-ro*, in both Russian and Polish, with the signification "good," "useful," &c., with an infinite number of derivatives. Although we might find other Indo-Germanic analogies for the root of the Russian *doróga*, "a road," it is only in the Hebrew דֶּרֶךְ *derck* and the Arabic درج *derej* that we have the exact

synonym. There are some Semitic roots which we should not understand without the help of the Sclavonic; thus טָבַח *dhâba^ch* is generally supposed to signify "he sacrificed;" but טַבָּח *dhabbâ^ch* means "a cook," אֲבַטִּיחִים *'havadhî^chîm* means "ripe melons," and the Arabic طبخ *dhaba^ch* means "he cooked," طباخ *dhabbâ^ch* is "a cook," and طباخ *dhabaîk* means "hot winds," so that we are led to the well-known Sclavonic word *tep-lei*, "warm," whence the name of the hot baths of Tœplitz; and we may assign the same origin to the title of the Scythian goddess of fire, which, as Herodotus tells us, was *Tabiti*. We might recognise the monosyllabic root of דָּבַר *dâ-bar* in *ver-bum*, as we might in the Sclavonic *go-vor-it'*, but it is only in the Russian that we have the genuine compound *do-varei*, as in *raz-dovarei*, "familiar discourse." The Greek δολιχὸς belongs to the Pelasgic or Sclavonian state of the language; in the Sanscrit *dîrgha*, Zend *daraga*, Behistun *daraga*, &c. the *l* is changed into *r*, but in all the Sclavonian forms the *l* is retained, as in *dolgie*, *dlauhy*, *dlugi*, &c., and the same is the case in Arabic طال *dhâl* for *dhôl*; Hebrew גָּ-דוֹל *gâ-dol*, "great," דָּלָה and דָּלַל *dâlâh* and *dâlal*, "to hang down." These examples, which are taken at random and might be multiplied to any extent, will suffice to show the nature of the resemblance between Sclavonian and Semitic roots. Nor is the resemblance confined to the roots. The mode of using them is also marked by features of similarity, and we have some cases in which these classes of idioms present solitary examples of a corresponding process of thought. Thus, it is a peculiarity of the Semitic race to regard "*four*," and especially its multiple "*forty*," as a round number or expression of indefinite plurality. Similarly, in Russian, we find that, although the other numbers are formed on a principle of internal development, the term for "forty" is *so-rok'*, which is not connected with *chetére*, "four," and is obviously a collective noun formed with the preposition *so*. Again, in common Hebrew we never find the simple relative *she*, but always the lengthened secondary form *'hasher*. Similarly in Sclavonic the simple form *koe* is only used in poetry; the lengthened form *kotorei*, *kotoraia*, *kotoroe*, which is equivalent to κοτοροῖος, being invariably employed in common discourse. The form *kto* is a variation of the impersonal *chto*.

(2.) But agreements of sound and even of usage are less conclusive, as proofs of common origin and ethnical contact, than a communion in those principles which regulate the structure of a language. And this remark particularly applies to the comparison of the Sclavonian language which exhibits a living power of etymology in its most active state, with the Semitic languages in which the development of the form has been checked and the whole stock of inflected words petrified into a congeries of triliteral fossils. Every person, who is acquainted with the Sclavonian languages, must have been struck by the fact, that none of the other Indo-Germanic idioms exhibit the monosyllabic roots in such a constant state of accretion or agglutination with the affix, prefix, or both. And with regard to the prepositional prefix in particular, there is certainly no class of languages which can vie with the Russian, *i. e.* the purest Sclavonian, in the number, variety, and constant use of these distinctive initials. Now modern philology leads us to the conclusion that the Semitic languages were originally built upon the same system of monosyllabic roots as the Sanscrit and Greek, and that the additions by which every such element is accompanied in the existing state of the language are formative appendages belonging to the time when the

etymological activity of the idiom was still unimpaired. According to this view, it is quite clear that the particular form of the Indo-Germanic languages, under which such a permanence of crude trigrammatism became possible, must have been that which we recognise in the Sclavonian family, namely, a state of accretion, in which the separability and independent significance of the monosyllabic root are no longer regarded, or taken into consideration. The converse phænomena, in the case of the Sporadic or Turanian languages, furnish the best illustration of the Semitic word—forms. It cannot be doubted that the tribes which supplied the continents of Asia, Europe and America with the first wide-spread sprinkling of population, migrated from the central district, while the monosyllabic root was still regarded as independent and separable, and the civilization which gathered round a fresh nucleus in China has not been able to deprive the monosyllabic language of this inherited characteristic. As then we have in the one case a juxtaposition of formative contrivances without any real fusion, we observe in the Semitic languages the development of etymology checked after it had assumed the concrete forms of Sclavonic agglutination. We require then, for the explanation of the only known condition of the Semitic languages, that ethnographic fact of Sclavonian antiquity to which another train of reasoning had already conducted us.

Again, it is a distinguishing characteristic of the Semitic languages to have a great abundance of derivative forms for the verb itself by the side of a striking parsimony in the inherent tense-forms. This is equally a characteristic of the Sclavonian idioms. The Semitic languages have no proper distinctions of tense as past and present; the forms which they use designate transient or momentary, as distinguished from continuous states or actions. The derivative forms which are called conjugations, such as *Niph'hal, Hiph'hil, Hithpa'hel,* are contrivances for expressing the various relations, degrees, and modes of agency. Precisely the same is the anatomy of the Sclavonic verb. Instead of the proper distinctions of tense, the verb-forms are divided according to the mode of action into branches or classes, which modern grammarians designate as semelfactive or monologous (in Polish *iednotliwé*) as opposed to frequentative or iterative (in Polish *czestotliwé*), and complete or perfect (in Polish *dokonane*) as opposed to incomplete or imperfect (*niedokonané*). A simple example will show, even to those who have not studied the subject, how completely the usual distinctions of tense are set aside by this mechanism. The Russian verb *trogat'*, 'to touch,' makes *ja trogaiu*, 'I am touching,' in the present tense of what is called the indefinite branch. But if we prefix the particle *ras*, we get *ja rastrógaiu*, 'I shall touch,' for the future of the perfect branch, which, in its so-called present *ja rustrogal'*, 'I touched,' exhibits all the characteristics of a past tense. In the same way, we find no real present tense in the semelfactive *tronut'*, 'to touch once,' and in the iterative *trogivat'*, 'to touch repeatedly,' but only the past forms *ja tronul'*, 'I touched,' and *ja trogival'*, 'I kept touching,' while the present form of the semelfactive *ja tronu* is used as a future, 'I shall touch.' This habit of substituting distinctions of complete or incomplete, of single and continued or repeated action, for the true distinction between past, present, and future, is peculiar to the Sclavonic as compared with other Indo-German idioms, but common to all the Semitic dialects. The internal or etymological modifications by which the change of signification is expressed are, of course, less distinct in the Semitic idioms, but they are still sufficiently apparent. Into the origin and value of these pronominal insertions, it is not my business to enter on the present occasion. I will only call the attention of scholars to the fact, hitherto unnoticed and unexplained,

that the insertion *nu*, which marks the semelfactive verb in Sclavonian, is never found in Sanscrit, Greek, or Latin with any trace of that reduplication which is the proper expression of repeated action. Thus we have *da-dâmi*, but *ap-nô-mi*; δί-δωμι, τίθημι, ἵστημι, but ζεύγ-νυμι, δάμ-νη-μι, ἱκ-νέομαι, &c.; πίπτω for πι-πέτω, but πίτ-νω; and Latin verbs which insert *n*, always omit this adjunct in the perfect, their only reduplicated tense; thus we have *tundo*, but *tutudi*. The syntactical contrivance by which the Semitic languages express the passive or reflexive voice is also introduced in Sclavonic verbs, which have no etymological mechanism for the purpose, although their person-endings are remarkably complete. I have shown elsewhere (*Maskil le Sopher*, p. 33) that the prefix of the reciprocal *hith-pa"hêl* is the subjective הִ combined with the objective אֵת, and that the passive *niph"hal* has for its initial the objective נ only. The Sclavonic verb absolutely subjoins the reflexive pronoun *sya* to all persons of the verb. It is useless to weary you by pursuing this grammatical comparison any farther. Those who have studied the refinements of philology will be able to estimate the argument from these hints, and it would be idle to present the details to those who take no interest in the subject.

But independently of the arguments deducible from these lexicographical and grammatical coincidences, there are certain phonological peculiarities, common to the Semitic and Sclavonian languages, which seem to me to confirm the view which I have taken of their original contact and congruity. It is well known to the philological student that whole families of languages have been discriminated by the different degrees in which they have maintained the integrity of their sibilants, or, in other words, by the various substitutes which they have allowed to supersede these more ancient articulations. In examining the sibilants of a particular language, we have to consider two classes of sounds: the original sibilants, which in secondary states of the idiom degenerate into mere breathings, or are softened into semi-consonants and vowels; and those palatal sibilants, which are themselves generated by a softening of guttural and dental consonants. The latter class of phænomena, to which we owe the constant employment of the ζ in Greek, and our own soft *g*, *j*, and *ch*, must be carefully distinguished from the causes which interfere with the permanence of an original assibilation. An example will show the nature of the difference. The substitution of an aspirate for an initial *s* is one of the main characteristics of the change from old or Pelasgian Greek to the classical Hellenism with which we are acquainted, and this substitution has very much diminished the use of sibilants in the language. On the contrary, the aversion to palatal sounds on the part of the Hellenes has almost invariably substituted ζ, which is a sibilant, for all the softened gutturals or dentals of the older dialects. This procedure, which a recent philological writer (Schleicher, *Sprachvergleichende Untersuchungen*, p. 33) has proposed to term *Zetacismus*, may take place in any language, in which a guttural or dental is affected by an immediate contact with *i*. But the evanescence of *s*, or its change into a mere breathing, belongs to a particular state or condition of language, and we may classify idioms according to this phænomenon. Thus the Pelasgian and Latin as compared with the Greek, the Sanscrit as compared with the Zend, the Erse as compared with the Welsh, retain an initial sibilant, which in the corresponding but later forms of the same language is consistently changed into *h*. The history of the Greek alphabet, with which we are best acquainted, teaches us that the effect has been to diminish the number of sibilants. In spite of the *Zetacismus*, the old Σὰν has vanished, and while ρ and ν have usurped many of the functions of *s*, usage has deprived ξ of one of its original employments. If on

the other hand we examine the Sclavonian alphabets, we shall be struck by the superabundance of sibilant articulations for which they furnish the expression. They are rich not only in palatals, but in varieties of pure dental assibilation. We notice precisely the same phonology in the Semitic dialects, but here the guttural and nasal breathings also play an important part. The Sclavonian alphabet, as is well known, is an adaptation of the Greek, increased by characters borrowed from the Armenian and Coptic. The author was Cyril, otherwise called Constantine the philosopher, who was brother to Methodius, bishop of Pannonia and Moravia. The Greek order is preserved with the following exceptions. Before *Vjedi* and *Zjelo*, which corresponded to the Greek βῆτα and βαῦ, Cyril inserted *Buki* and *Zivjete*, and remanded to the end those letters peculiar to the Greeks, namely ξ, ψ, θ, and υ. The alphabet thus enlarged contains the following sibilants: (*a*) pure dentals, *zjelo, zemlja, slovo, tzi*; (*b*) palatals, *cero, sha, shcha*, besides the compounds *ksi* and *psi*. If we take the Arabic as the most extensive form of the Semitic alphabet, we shall find that it contains the following sibilants: (*a*) pure dentals, *thse, dsal, ze, sin, ssad, zza*; (*b*) palatals, *jim, shin*. The Hebrew, which has its full complement of pure dental sibilants in *zain, tsade*, and *çamech*, has no palatal except *shin*. Now as the palatals are softened or degenerated forms of the gutturals, it is a natural consequence that the guttural aspirate should abound in proportion as the palatal is wanting. This is strikingly the case in Hebrew, which has no less than four distinct aspirates, '*haleph, he*, ^{c}*heth*, ^{n}*hayin*, besides its guttural mutes *gimel, kaph*, and *koph*. The only approximation in Hebrew to that softening of the gutturals, to which the formation of zetacised articulations may be ascribed, is to be found in the semivowel use of *yod*, which is undoubtedly the offspring of the gutturals. But it is never so combined with gutturals or dentals as to form a pure palatal sound, unless we recognise it in *shin* as a substitute for *sk*. Reverting then to the principle which enables us to distinguish between the pure sibilant and the subsequently formed palatals, we shall come at once to the conclusion that the Semitic and Sclavonian languages exhibit a complete coincidence in regard to their unimpaired development of the original sibilant, for they alone possess the three sounds of *zain* and *zemlja*, of *tsade* and *tsi*, of *çamech* and *slovo*; and while the formation of palatals has proceeded to its full extent in Sclavonian and Arabic, the permanence of the pure sibilant in Hebrew is shown by the fact, that with a full array of breathings there is no diminution in the use of the sibilants in *anlaut* or as initials. The force of this observation will be felt by those who know that even in the Zend, as compared with the Sanscrit, the transition from the initial *s* to an initial *h* has established itself in uniform observance. Important conclusions to the same effect may be derived from the palæography of the cuneiform characters, which have preserved to us a record of the Median or Sclavonian idiom at the earliest known period of its subjection to Persian or Germanic influences. If we examine this alphabet, we shall see that the arrangements of the arrow-heads or wedges, of which each character is composed, are not casual, but technical and systematic, having reference to a perception, more or less scientific, of the true affinities of articulation. Thus we shall see that all the characters, which are connected with the lateral angle 〈 turned to the left, are more or less affected by aspiration. The distinct aspirate *h* has two of these marks, and the inclusion in this character of *n* only shows that, like the Hebrew ^{n}*hayin* ע, it was regarded as a nasal breathing. As *d* and *r*, the affinity of which is well known, are but slightly different forms of the same character in the Semitic lan-

guages (ד, ר, ܕ ܪ), and as *r* and *z* (ر ز) are similarly related in Arabic, we find in the cuneiform alphabet that *r* and *s* are represented by the same character turned in different directions (for *r* is 𐎼 and *s* is 𐎿). With these indications of contrivance and design, it becomes important to note that a lateral mark only distinguishes *s* 𐎿 from *v* 𐎺. For as Col. Rawlinson has shown that the character which he calls *u* 𐎢 has an inherent aspiration, and as *hu* is, in the passage from Sanscrit to Zend, the representative of *sv*, we find thus in the very contrivances of the alphabet an explanation of that transition from the sibilant to the breathing, and from the labio-dental to the vowel *u*, which is the main characteristic of the Persian as distinguished from the Median, and of the Græco-German as contrasted with the Pelasgo-Sclavonian idioms. Compare, for example, the transitions of sound in the Sanscrit *çvan*, Median *çpaka*, Russian *sabac*, Greek *κύων*, German *hund*; in the Russian *svera*, Lettish *svehrs*, Latin *fera*, Greek *θήρ*, English *deer*; Sanscrit *svapna*, Greek *ὕπνος*, and so forth.

Putting all these circumstances together, there cannot, I conceive, be any doubt that the Sclavono-Median language furnishes us with the point of departure and line of demarcation between the Indo-German and Semitic families. With the most pronounced differences of subsequent condition, the Semitic and Sclavonic idioms exhibit those marks of internal resemblance which could only spring from contact and intermixture at a very early period, and this contact and intermixture are preserved in all that we can learn respecting their geographical settlements respectively. And it is as easy to explain the differences as it is to account for the resemblances. The Sclavonian languages are the most full in etymology and the most meagre in syntax of all varieties of Indo-German speech, because the race has remained pure, and because it did not till a late period adopt alphabetical writing or encourage the development of a national literature. The Semitic idioms, on the contrary, are the most completely fossilized in etymology and the most distinctly syntactical of all languages, because the races which spoke them were constantly exposed to fusion and intermixture, and because they were the first to adopt alphabetical writing and the earliest possessors of literary records. The effects, which an admixture of different races, whether proceeding from migration or conquest, produces upon the inflexions of a language, have long been recognised, and the familiar illustration furnished by the modern English language, as the result of a combination of the Norman with the Anglo-Saxon, has often been adduced. But perhaps I shall not make my meaning as clear as I could wish without adding a few remarks on the influences of alphabetical writing and literary cultivation; for sufficient attention has not been paid to the fact that these influences are most decisive and permanent when their first operation is contemporaneous.

Alphabetical writing was not invented by one effort. It is the last result of a series of successive improvements. The first step is a system of picture-writing or significant signs, which is the usual concomitant of an application of art to the service of idolatry. The constant use of an ideographic picture in connexion with the name of a particular object leads to its employment as a determinative initial for all names which begin with the same or a similar sound. Hence we have phonetic signs intermixed with emblems or pictures. A further step in advance takes us to combinations of phonetic signs alone, and a greater use of writing naturally leads to abbreviations and cursive forms of them, which are first syllabic and then literal. This is the origin of alphabetic writing. Whether there has been more than one invention of the art, or whether all existing alphabets may be traced back to a common

source, are still open questions. Thus much, however, is certain, that all the civilized nations with which we are acquainted in Asia and Europe, have either passed through the various steps of the process which I have just described, or have borrowed the Semitic syllabarium in some stage or other of final development.

It is by no means necessary that the use of alphabetic writing should precede the formation of a national literature. On the contrary, the purely epic period in a national literature will generally, if not always, precede the adoption of a mode of writing calculated to supersede the memory, especially in the case of those languages which still retain their etymological structure, and are thus calculated to meet the exigencies of uniform metre, and to pass, by oral teaching, from one generation of bards to another in unbroken succession. It is pretty clear that the Pali literature of the Buddhists was committed to writing long before the Brahmins borrowed from them the means of writing down their old epic and religious poetry. So that although the Sanscrit language is in a more perfect etymological condition than the Pali, and though the *Vêdas* and even the *Mahâbhârata* are older than the Pali inscriptions, the records of the Sanscrit literature are preserved in borrowed characters of comparatively recent date. Notwithstanding all that has been written on the Homeric question, it remains a fact that the epic poetry of the Greeks is of earlier date than their adoption or familiar use of the Semitic alphabet. The result has been, in both cases, that the forms of the words in Greek and Sanscrit retain their exuberant fullness, which in the former language is unaffected even by the existence of a perfectly logical syntax. The converse cases are furnished by the Old Egyptian and Chinese languages, which never entirely shook off the symbolical and sensual reference of their written characters. The Egyptian, indeed, did in the end arrive at a purely phonetic use of its hieroglyphic signs; but the Chinese never lost the point of departure suggested by their *siáng-híng* or "figurative images;" the highest abstraction being that of the *híng-chíng* or "figurative sounds," which however were always combined with ideographic or pictorial signs. The palæography of the Semitic nations lies half-way between that of the Greeks and Indians, who adopted no system of writing except the alphabetic, and did not make use of this until their poetical literature had taken root and began to flourish; and that of the Chinese and Egyptians, who employed picture-writing instead of their memories from the very earliest period, and who never attained to a perfectly abstract and simple alphabet. I believe that the first Semitic alphabet was due to the Hebrews rather than to the Phœnicians. The Sacred History of this nation tells us that their great legislator was educated in Egypt at a time when the phonetic hieroglyphs were in general use, and there cannot be the least doubt that the Phœnician and Hebrew characters may be traced to particular signs in the Egyptian syllabarium. Some very satisfactory specimens of this have been given by Mr. Hensleigh Wedgwood in the 'Transactions of the Philol. Soc.' vol. v. No. 101. It has always appeared to me a most interesting fact, that we should owe our first alphabet to the same race from which we derive the foundations of our religion. Picture-writing and picture-worship are intimately connected. Abstraction is anti-idolatrous, and is manifested in the invention of an alphabet quite as much as in the adoption of a pure theism: nor would I quarrel with any one, if he thought fit to ascribe to the same inspiration, the Commandments written on the two tables of stone, and the simple characters by which they expressed their meaning. Be this as it may, it seems pretty clear that the Hebrews never had any but an alphabetical system of writing; and it is also clear that they had no literature except that

which was written down alphabetically. The same may be said of the other pure races of the Syro-Arabian family; and this alone will explain the permanence and uniformity of their syntactical structure.

With regard to the cuneiform characters, I cannot doubt that they are of Mesopotamian and therefore of Semitic origin. Internal evidence shows that their origin was not immediately hieroglyphic, but that they emanated from a system of phonetic writing in which affinities of articulation are fully perceived and recognised. The form of the character was regulated by the materials. The alluvial plain of the two rivers furnished abundance of brick earth, and nothing could be more simply ingenious than to form a set of letters which might be made by impressions on the unbaked clay struck with the end of an iron tool, and arranged in different groups according to a technical plan or convention. The lapidary character which was subsequently imparted to this mode of writing does not interfere with our evidences of the fact that the cuneiform letters were the natural and simple invention of a people of brickmakers, who had abundance of clay, and no hewn stones to write on. In these days of note-paper and envelopes we do not sufficiently consider how much the mode of writing, in the first beginnings of the art, depended upon the nature of the stationery. The *ostracism* of Athens and other cities, and the *petalism* of Syracuse show what difficulties were caused by a general demand for slips of paper. When the great body of citizens in those populous towns wished to get rid of an obnoxious statesman, it was usual to effect this by writing down the name of the party to be exiled and sending it in as a ballot-paper. In the want of other substitutes for waste-paper, the Syracusans employed olive-leaves, and the Athenians, Argives and Megarians used fragments of broken pottery, *i. e.* pot-sherds. It is amusing to observe how the old blunder about the ὄστρακον still maintains its ground. Even Mr. Grote talks of votes given by means of oyster-shells! To say nothing of the fact that ὄστρακον never meant an oyster-shell, how would they write on such a material, and whence would they obtain such a superabundance of these shells? On the contrary, the most economical and abundant substitute for waste-paper would undoubtedly be broken pottery; a *mons testaceus* might be formed in any town where porcelain is used; and any pointed instrument would scratch the obnoxious name on a piece of tile or broken vase.

But while we can explain the cuneiform writing even down to the origin of the characters of which it is composed, and while we can not only read the Cartouches of Egyptian kings, but discuss the first beginnings of hieroglyphic writing, it certainly is most unsatisfactory to reflect that we cannot understand the remains of the Etrurian language, which we find in the midst of the old Italian civilization, written in a character with which we are familiar, belonging to a well-known historical epoch, and surrounded on every side by literary and linguistic associations. It is the remaining object of this paper to show, by a process of ethnographic exhaustion similar to that which I have employed in discussing the Semitic question, that there can be only one solution of the Etruscan problem, and that if we cannot explain everything in the inscriptions, we can at least see the limits within which their explanation is possible, the line of motion in which our future progress must take place, and the goal at which we must ultimately arrive.

Looking at the population of Europe just as we should regard the geology of a district, we must recognise the following ascertained facts in the stratification of the Indo-Germanic family. The eastern half of Europe, from the Baltic to the Mediterranean, is filled by different branches of the Sclavonian family. In the south no less than in the north these Sclavonians abut upon

members of the Gothic or Low-German race, with whom of course, on the oscillating boundary-lines of the two families, they are intermixed in different degrees of fusion. Such an intermixture by the side of pure Sclavonism we find in the Lithuanians of the north and in the Latins of the south. There cannot be any doubt as to the Sclavonian origin of the Tyrrheno-Pelasgian race. There cannot be any doubt that the other element in the old population of Italy was, like the Lithuanian, a mixture of the Sclavonian and Gothic. As then, in the north, our next transition is to the Scandinavian or purely Gothic race, it is reasonable to conclude that the Rasena, who conquered Umbria and Tuscany, and who are expressly described as a neighbouring tribe, must have been either pure Sclavonians or pure Goths; for there was no Celtic tribe in that district. But it is clear that if they had been Sclavonians, their language would not have differed so strikingly from that of the Tyrrheno-Pelasgians. It follows therefore that they must have been pure Getæ, Goths, or Low-Germans. This is the inevitable result of the *primâ facie* evidence. Let us see how it is borne out by the remains of the Etruscan language and by the traditions respecting this nation.

To begin with tradition, there cannot be a more definite ethnological statement than that in Livy (v. 33) which connects the Etruscans with the original inhabitants of Lombardy and the Tyrol, on whom the Gauls afterwards encroached. That the Rhæti in particular were of the same stock as the Etrusci is stated also by Justin (xx. 5) and Pliny (*H. N.* iii. 25), and relics of art, names of places, and peculiarities of language tend to confirm the ethnical tradition. Niebuhr (ii. 525, i. 113, 114) is favourable to the conjecture, that the Etruscan race, which maintained its ground among the Alps, with Gauls all round it, must at one time have spread along the northern skirts of those mountains and into the plains of Germany. Be this as it may, we find that all along the eastern boundary-line of the Sclavonic population, wherever they abut on Teutonic tribes, they have received from their neighbours the name of *Wind* or *Wend*. What this name signifies is quite unknown, but it is certain that it is not the Sclavonian or native designation, for that, as we have seen, is *Serb* or *Servian*. And it is reasonable to conclude that it is a Gothic or Low-German name, given to the Servians by their Teutonic neighbours. Now we find that the Etruscans in Lombardy called their neighbours to the east *Veneti*, and that the Etruscans in Rhætia called their eastern neighbours *Vindelici*, or "Winds on the Lech." The fair inference would be, that the Rhæto-Etruscans were a Teutonic tribe, and, if Teutonic, they must have been of the Scandinavian, Gothic, or Low-German branch. If we are compelled to recognise the same admixture, and indeed the same name, in the *Lithuanians* of the north and the Latins or *Latuinians* of the south, we must recognise also the same juxtaposition of separate elements in the Scandinavians who stand opposite to the Sclavonians on the Baltic, and in the Rhætians who face the Wends in central Europe. Consequently, if we accept the tradition which identifies the Rasena with the Rhætians,—and I agree with Dr. Latham that it is entitled to the greatest consideration,—we must also identify them with the Scandinavian race.

On the philological confirmation of this tradition I hope to throw some new light in the remarks which follow. It is unnecessary to repeat the statements of Lepsius and others respecting the composite structure of the old Etruscan language, and the different degrees in which the Pelasgian or quasi-Greek element prevails in it. There can be no doubt that the civilization of northern Italy is due to the Tyrseno-Pelasgians, and that they belonged to the same branch of the Sclavonic race which constituted the basis of the old Achæan population. Their name Τυρσηνὸς, as Lepsius has

shown, signifies 'the tower-builders.' I am prepared to prove, that both in Greece and Italy the Pelasgians were the original architects, that the Dorians in the former case, and the Etruscans in the latter, borrowed the arts of the nation which they subdued, and that the so-called Dorian architecture was imported, in a complete form, from Asia Minor. Just in the same way we find that the North American *Aztecs* who conquered Mexico adopted the arts which the civilized *Toltecs* had previously established there. It is worthy of remark that the name *Toltec* is a synonym for 'architect' (Prescott, *Conquest of Mexico*, i. p. 12). Their capital *Tula* may therefore be compared with *Tyrrha*, from which the *Tyrrhenians* derived their origin. In general, the mixed race of *Aztecs* and *Toltecs*, which Cortez found in Mexico, with their gorgeous luxury, their skill in cookery, &c., remind one very much of the Etrurians.

On the fullest consideration, I cannot assent to the opinion of Otfried Müller (*Etr*. i. 71), that the name *Etruscus* is another form of *Tyrsenus*; and in spite of its alluring facility, I feel myself obliged to abandon the favourite hypothesis that *Rasena* is a mutilation of *Tarasena*, the genuine form of the Pelasgian designation. The true philologer will find the proofs of a common origin in forms presenting to the unskilful eye the marks of an almost total dissimilitude, and he will also, in many cases, reject as inconclusive the most striking evidences of merely outward resemblance. He knows, for example, that *sero, sertus*, is a different word from *sero, situs*; and that the concessive *modo* has no connexion with the ablative of *modus*. It is therefore not a scientific procedure to conclude that *Etruria* and *Etruscus*, which always begin with *E* or *He*, are elongated forms of *Tuscus* and *Tyrsenus*; or conversely that *Rasena* is a mutilation of a more original word beginning with *T*. If we admit the *Rhætian* origin of the Etruscans, the name *Rasena* must stand. And as *Et-rus-ci* or *Het-rus-ci* presumes an original *Het-rus-i*, it would be more reasonable to conclude that this term comprises the root *ras*, with a significant prefix, and Niebuhr has shown that *Ras-ena* contains this root with the affix *-ena* found in *Pors-ena*, &c. The old Scandinavian will tell us what this prefix means; for in Icelandic *hetia* is 'a warrior or soldier,' and in the same language *ras* implies rapidity of motion: so that the *Ras-ena* and *Het-rusi* would be as good names for a warrior tribe as πόδας ὠκὺς was for Achilles, and θῶες for a troop of predaceous animals. Another identification of similar roots must be equally avoided. Nothing is more natural at first sight than to suppose that the names Ταρχώνιον, *Tarkynia*, *Tarquinii*, are harder forms of the Pelasgian Τυρσηνός. But there is a conclusive reason against this assumed identity, which has not yet occurred to any philologer. If ταρχ- or τραχ- and τυρ-σ- belonged to the same root, the latter must be a secondary or assibilated form of the other. Now to say nothing of the fact that the σ- of τυρ-σηνὸς and τύρ-σις belongs to the termination, and is not found in τύρ-αννος, &c., it is clear that the form τυρ-σηνὸς is the only one which was ever known to the Pelasgians in Greece, whereas the harder form belongs to the later or mixed race in Italy. It would be, therefore, more reasonable to conclude that while Τυρ-σηνὸς is the *Pelasgian*, whether in Italy or Greece, the *Tar-chons* and *Tar-quins* belong to the Etruscans properly so-called. Now if we admit this, we at once fall back upon the Scandinavian race. For the prefix *Tor* or *Thor* is a certain indication of the presence of the North-men. Thus we have the town of *Thor-igny* in the N.W. of Normandy, where the termination is the same as that of many other towns in the same district, as *Formigny, Juvigny*, &c., and corresponds to the Danish termination *-inge*, as *Bellinge, Helsinge*, &c. (Étienne Borring, *Sur la Limite méridionale de la Monarchie Danoise*. Paris, 1849, p. 9). It is worthy of remark

that the word *-ing*, which is appropriated by the *Ing-ævones, Angli, English*, and other pure Low-German tribes, seems to signify 'a man,' or 'a warrior' (Grimm, *D. M.* i. p. 320), and as *quinna* is the Icelandic for *mulier*, *Tor-ing* and *Tar-quin* are antithetical terms. The Low-German name *Tor-quil* is probably a by-form of the latter; at any rate we cannot but be struck by the resemblance of these Northern and Etruscan names. The mythical *Tanaquil* of Etruria reminds us of *Tanaquisl*, the old Scandinavian name for the Tanais, which however is feminine (Grimm, *D. Gr.* iii. 385).

It is obvious that we cannot expect to find one uniform language in the Etruscan Inscriptions, which belong to very different epochs, and are scattered over the whole of the territory occupied in different proportions by a mixture of cognate tribes. In the most ancient fragments, and especially in those which are found in the south of Etruria, we should expect to find a predominance of the Pelasgian element, which is common to Greek and Latin: and in point of fact, many of these inscriptions differ little, if at all, from Archaic Greek. We should have no difficulty about the remains of the Etruscan language, if all the fragments were as easily deciphered as *mi Kalairu fuius*=εἰμὶ Καλαιροῦ Ϝυιός. In some we find not only the Greek language, but the Hexameter line, which is peculiar to the Greeks; thus we have, in the Museum at Naples, the following line: *mi ni Mulve neke Velthu, ir Pupliana*, "I am not Mulva nor Volsinii, but Populonia;" and we find a complete couplet on the vase found by Galassi at Cervetri:

mi ni kethuma, mi mathu maram lisiai thipurenai;
ethe erai sie epana, mi nethu nastav helephu,

"I am not dust, I am ruddy wine on funereal ashes: where there is feasting under-ground, I am water for thirsty lips." In other inscriptions we naturally find a nearer approximation to the Umbrian language, as represented by the Eugubine tables. And I propose to show that where we cannot derive any assistance from Pelasgian or old Italian sources, the Scandinavian languages will furnish us with certain and ready help. I must premise, however, that I do not intend to engage in any detailed explanation of the Etruscan inscriptions: it will be sufficient for my present purpose, if I can, by a few decisive instances, establish the character of the language, and thus confirm the other proofs of Scandinavian or Gothic affinity.

With this view, the proper mode of proceeding, as it appears to me, is to begin with those inscriptions which involve repetitions of the same phraseology, and of which the *primâ facie* interpretation is most simple and obvious. When, for example, we find on sepulchres such inscriptions as: *eca suthinesl Titnie* (Dennis, i. 242. p. 443), or *eca suthi Larthial Cilnia* (Dennis, i. p. 500), or *kehen suthi hinthiu thues* (Vermiglioli, i. p. 64), or *eka suthi amcie Titial* (Vermigl. i. p. 73), we can hardly doubt that *eka* and *kehen* are either adverbs or pronouns signifying 'here' or 'this,' in accordance with the root which appears in all the Indo-German languages, and that *suthi* implies either lamentation or recollection. Now in Icelandic *sut* is *dolor, mœstitia*; and, in the same language, *nesla* or *hnesla** is *funis, laqueus*; so that we might translate *eka suthinesl Titnie* and *eka suthi Larthial Cilnia* by: "this is the sorrowful inscription for Titinius," and "this is the mourning for Cilnius the son of Larthius." If this were an isolated parallelism between the Scandinavian and Etruscan, it would prove little beyond the fact that there is a certain similarity of sound between the two languages. But by the side of the *eka* or *kehen*

* In the transition from Icelandic to Swedish, *h* falls away before all consonants; thus *hnyckr* becomes *nyck*, &c. The same occurs in Latin, as in *res* for *hra-is*, from *hir* = χείρ. The root of *hne-sla* is *ne*, the termination being *sla*, as in *reyn-sla*, &c.

suthi we have *cen phleres trce* (Vermigl. p. 31) and *eka erske nak achrum phler-thrke* (Dennis, i. xc.); where *phleres* differs from *suthi* in being the designation of moveable objects rather than of fixed monuments or sepulchres. Thus we have *ken phleres teke* (or *trke*) on the toga of the statue of Aulus Metellus (Micali, *Antichi Monumenti*, pl. 44. n. 2), and on the left thigh of the laurel-crowned Apollo (Gori, *Museum Etruscum*, i. pl. 32) we have the legend: *mi phleres Epul aphe Aritimi, Phasti Ruphria turce clen cecha.* From these and a number of other examples it is clear that *phleres* must denote the object offered up or consecrated. As most of the objects are of the nature of supplicatory gifts, it would be natural to suppose that the word denotes a votive oblation. Now we know from Festus (p. 230, cf. 77, 109) that *ploro* and *imploro* or *endoploro* in old Latin signified 'to call for aid.' If then we compare the Icelandic *fleiri*, Suio-Gothic *flere*, with the Latin *plures*, we shall easily see how *phleres* may contain the same root as *ploro*, especially since the Latin language recognises a similar change in the cognate *fleo*. The word is then in its effect equivalent to the Greek ἀνάθημα, and means a "votive offering," like the *votiva tabella* of the ancient temples, or the *voto* of the modern churches in Italy, and it is easy to see how the ideas of 'vow,' 'prayer,' and 'offering,' run into one another. But though we can at once translate *mi phleres Epul aphe Aritimi*, "I am a votive offering to Apollo and Artemis," this does not tell us the meaning of the word *trce* or *thrce*, which in the other cases is appended to *phler* or *phleres*. Here the Scandinavian languages at once come to our aid; for in Suio-Gothic *træga* is *dolere*, and *træge=dolor*; and in Icelandic *at trega* is *desiderare* and *tregi* is *desiderium* or *mœror*; and to the same root we may refer the Icelandic *threk=gravis labor* or *molestia*, for *tregi* also means *impedimentum*. Now as the monuments on which *thrce* or *trce* occurs are clearly sepulchral, it follows that *phler-thrce* must mean "a votive offering of sorrow." The inscription *eka erske nak achrum phler-thrke* appears on an amphora found at Vulci and in connexion with a picture representing the farewell embrace of Admetus and Alcestis. It may be assumed then that the amphora was a funereal offering from a husband to his deceased wife. We learn from Galassi's vase that *era* in Etruscan signifies 'earth,' and therefore *er-ske** would naturally denote an earthenware vessel; *nak* is the preposition which, under the form *na, nahe, nach*, occurs in all the Teutonic and Sclavonian languages; and *achr-um* is the locative of *achr=acker, ager*, which occurs in the great Perugian inscription; so that the legend signifies: "this earthen vessel in the ground is a votive offering of sorrow." It is as well to mention that I do not consider *turce* on the statue of Apollo as connected with the word *thrke*: its position between the proper name and the well-known *clen* shows that it is a family adjunct; and as the word *ceca*, compared with *cechaze* on the Perugian Inscription (l. 45), and with *cechase* on the Bomarzo Sarcophagus (Dennis, i. p. 313), seems to be a reduplicated verb-form (perhaps akin to the Icelandic *kasa*, Danish *kokase*, 'to heap up,' or 'build,'—perhaps connected with *gefa, geben*, χέϝω, &c.), we may render the passage thus: "*Fastia Rufria, Tusci filia natu maxima, dedit.*"

It is not necessary for my present purpose to pursue these comparisons of individual words any farther. Arguments of this nature are always more or less precarious, and no number of instances would be more decisive than the fact that the Scandinavian *sut=dolor* and *træge=dolor* stand under the forms *suthi* and *treke* on funereal monuments in Etruria. I shall therefore withhold the other examples which I have collected, and direct your attention to

* The termination *-ska* is very common in derivative Icelandic nouns, as *bern-ska*, 'childishness,' *ill-ska*, 'malice,' &c.

a grammatical identity between the Icelandic and Etruscan, which appears to me to furnish an indisputable proof of affinity.

No one can have read any of the Runic inscriptions without noticing the constant occurrence of the auxiliary or causative verb *lata*; thus we have: *Lithsmother lit akva stin aufti Julibirn Fath*: i. e. "Lithsmotherus incidi fecit saxum in memoriam Julibirni patris." *Thorstin lit gera merki stir Suin fathur sin*: i. e. "Thorstinus notas fieri fecit in memoriam Suini patris sui." *Ulfkitil uk Ku uk Uni thir litu raisa stin iftir Ulf fathur sin*: i. e. "Ulfkitillus et Bos et Unius, hi fecerunt extollere saxum in memoriam Suini patris sui." (See other instances in Dieterich's *Runen-Sprach-Schatz*, p. 372.) Now here we have, as part of a constantly recurring phraseology, an auxiliary verb signifying 'to let' or 'cause,' followed by an infinitive in *-a*. If then we had nothing else to induce us to suppose that there was some connexion between the Scandinavians and Etruscans, we should be struck by the coincidence that the largest of the Etruscan inscriptions, that of Perugia, actually begins with this phraseology: "*eu lat tanna La Rezul amev achr Lautn Velthinas*." Of course there is no *primâ facie* reason to conclude that *tanna* is a verb; on the contrary, I am well aware that it has been generally considered as a feminine prænomen, found, for example, in the name *Tana-quil*. It so happens, however, that I have recently been favoured with the means of confirming the supposition which brings this celebrated record into contact with the old Runic inscriptions. A small patera, brought from Chiusi by my friend Mr. J. H. Porteus Oakes, and now in the Bury Museum, contains the following legend: "*stem tenilaeth nfatia*." The very first glance at this must convince us that *tenilaeth* is the third person of a transitive verb, the nominative being *Nfatia*, probably the name of a woman (cf. *Caphatial*= *Cafatia natus* in Dennis's Bilingual Inscription, ii. p. 475), and the accusative being the pronoun *stem* for *istam*. The verb *tenilaeth* obviously belongs to the same class of forms as the agglutinate or weak-perfects in Gothic, which are formed by the affix of the causative *-da*, as *soki-da*, "I did seek" (Gabelentz u. Löbe, *Goth. Gramm.* § 127). We have the same formation in the Latin *ven-do*, *pen-do*, &c., and I have indicated the existence of a remarkable class of causatives in *-so*, *-sivi*, as *arces-so*, *capes-so*, *quæ-so* (*Varronian.* p. 207, 252). We may therefore see that *lat tanna* represents as separate words what *teni-laeth* exhibits in an agglutinate form, the auxiliary, in the latter case, however, being in the present tense, which in Gothic is formed in *th*; and *lat* being a strong perfect. With regard to the verb *tana*, *teni*, it is clearly the same as the Icelandic *then*, *at thenia*=*tendere*, O.H.G. *danjan*, *denjan*, A.-S. *dhenjan*, N.H.G. *dehnen*, Gr. τείνω, τανύω, Sanscrit *tan-*, and therefore signifies "to offer," like the Latin *porrigo* or *porricio*. As *ten-do*, which is an agglutinate form quite analogous to this *teni-lata*, is really synonymous with *porrigo**, we have in the cognate and conterminous Latin and Etruscan languages a perfect compendium of ritual phraseology; and *stem tenilaeth N'fatia* is quite as near to *istam ten-dit* or *porrigit Nefatia* as we should *à priori* expect. The Perugian inscription is, however, even nearer to the Runic than this patera legend is to the Latin; and the evidence furnished by the two, taken together, seems to me conclusive. Without entering upon any lengthened examination of the Perugian monument, I will only remark that *lautne*, which occurs in other Etruscan inscriptions (Vermiglioli, p. 64), is best translated by a reference to the Icelandic *laut*=*locus defossus*, so that the beginning of the document will signify: "Here Lars Ræsial let offer or give a sepulchral (*ama*, Icel.=*ango*) field as the grave of Felthina." As we have elsewhere

* Thus we have (Cic. *de Orat.* i. 40, § 184): "præsidium clientibus atque opem amicis et prope cunctis civibus lucem ingenii et consilii sui *porrigentem* atque *tendentem*."

lautnescle (Vermiglioli, p. 64), so we have shortly after *kemulmleskul*, and it would be curious if it were only by an accidental coincidence that *kuml* is the regular Runic name for a monumental stone: thus we have *ku lit rasa kuml*, i. e. "Bos fecit erigere monumentum" (Dieterich's *Runen-Sprach-Schatz*, p. 124).

The companion patera or saucer to that which I have just examined contains an inscription, of which a fac-simile has been kindly sent to me by its possessor, Mr. Beckford Bevan, and which tends to confirm what I have just said. The words are: *flenim θekinθl θm-tf-lan-eθ*. In Icelandic *flenna* is=*hiatus, chasma*, so that *flenim* may=*pateram*. *Þam=egelida obscuritas aëris*; *tef=morari*; and *lán* (*at lána*)=*mutuum dare, credere, commodare*, English *lend*,—so that the compound verb may denote, "he *lendeth* for a dark dwelling," and the inscription means: *Thekinθul dat pateram ad commorandum in tenebris*. The Icelandic has compounds of nouns and verbs, as *hálshoggra*, 'to behead,' and also of verbs with other verbs, as *brennimerkja*, 'to brand.'

And here I must conclude this paper. It was not my intention to discuss at length all the topics on which I have touched. To do this, I must have written a volume. Enough has, I think, been said for the fulfilment of the object which I proposed to myself at starting—namely, to indicate the direction of my own researches, and to invite either sympathy or correction from those who are engaged like myself as labourers in the great vineyard of ethnographic philology.

Report on the British Annelida. By Thomas Williams, *M.D. Lond. University, Extra Licentiate of the Royal College of Physicians, and formerly Demonstrator on Structural Anatomy at Guy's Hospital.*

Historical Introduction.

Into the nomenclature of Zoology the word '*Annelida*' is of comparatively recent introduction. Ancient naturalists adopted the term *Vermis*, plur. *Vermes* = *Worms*, as denotive, generally, of all lower animals resembling in form the leech and the earth-worm. In this uncircumscribed acceptation the latter word prevailed in use among naturalists down to the epoch of the writings of Lamarck. Appellations no less indefinite were employed by the Greeks in characterizing all forms of animals distinguished by soft and elongated bodies. The words σκώληξ, εὐλαὶ, ἕλμινς, were used by the Greek writers as names of different animals marked by the common character of a vermiform figure. The σκώληξ of Aristotle is evidently paronymous with the Latin *Vermis*, and this latter word is conjugate with *verto, to turn*, = i. e. *tortuous*. All animals whose movements were *tortuous*, were known under this designation. The Aristotelian word probably related only to the larva of insects. The *Scolex* of Ælian, however, is limited in its application to the earth-worm: by Ctesias, a still more ancient author, the same expression conveys the idea of some fabulous animal, engendered and nourished in wood. The *Scolezia* of Athenæus denotes a parasitic worm peculiar to the mule.

The second Greek term, εὐλαὶ, seems to have been one of less extended employment, and to have been restricted in its application to the *larvæ* of insects. In many of the works of Hippocrates, the word ἕλμινς occurs as

the definite designation of the class of animals now known as the *intestinal worms*. By Ælian and Aristotle, this term has also been employed under the same signification. The *Vermis* of Pliny comprehends in extent of meaning the three Greek terms already explained, and by this illustrious naturalist it was that the intestinal worms were first grouped under the special denomination of "lumbricus," the *Vermes* of Pliny having a co-extension of meaning with the modern term *worms*. Neither this word nor the French *vers*, both of which are traceable to a Latin origin, conveyed any clearly bounded ideas as to the zoological place and form of the animals of which they became the conventional names. In the writings of Lucretius, the word *Vermes* is thus used: "*Videre licet vivos existere Vermes stercore de tetro*." In the works of Celsus, the substantive *Lumbricus* occurs in the following sense, "terram rimentur, effodiantque lumbricos."

Der Wurm of the Germans, *Vers* of the French, and *Worms* of the English, are in the vernacular of these three people no doubt representative or equivalent expressions, all employed in an equally confused acceptation. Among the Romans, the generic name of *Exsanguinia* was subsequently introduced to signify those animals, previously comprehended under the all-embracing denomination of *Vermes*, of which the blood was colourless, viz. the Insecta, Mollusca and Zoophyta of modern zoology. It was not, however, until the æra of the naturalists of the last century that the old Latin word *Vermes* reached the full vagueness of its sense. In consequence of having united in the definition of the term, the consideration of the softness of the body to that of its elongated form, it came to embrace in the range of its application all animals, except the Vertebrata, Insecta, and Crustacea. To the authority of Linnæus is ascribed by Cuvier this undue extension of the word, since anteriorly to the epoch of the Swedish naturalist, Isidore of Seville had grouped under the class *Vermes* such animals only as might with zoological propriety have received that appellation.

To the ancients, the marine worms circumscribed within the modern class Annelida were almost wholly unknown. The Nereides are probably identical with the marine *Scolopendræ* of Aristotle; leeches and intestinal worms were also familiar to this author. In the writings of Ælian, Oppian, Dioscorides and Galen, and even those of Pliny, no additions to the natural history of these animals occur. By each, the sagacious statements of Aristotle are servilely copied or grossly exaggerated. By Isidore of Seville, the attempt was first made to classify the Lumbrici, Ascarides, leeches and flesh-worms in an independent group. In his work on the Animals *exsanguinia*, Albertus Magnus alludes to the leech and the earth-worm in alphabetical order. Wotton has not extended the number of the animals of this class, and only speaks of the Nereides under the name of *Marine Scolopendræ* in his book upon Insects;—of leeches among the fish; and of earthworms under the name of *intestini terræ*, as well as of intestinal worms under the generic denomination of *Lumbrici*, *Elmins* of the Greeks, among the insects. Belon, in his History of Aquatic Animals, mentions for the first time under the phrase *lumbricus marinus*, in opposition to the earth-worm, which he names *lumbricus terrestris*, the worm which is now known as *Arenicola Piscatorum*. It is susceptible of historical proof that to Rondelet is due the merit of having first clearly defined the genera of marine Annelids now characterized as the *Nereides*. In his work, under the head of Sea-Scolopendra, figures of these worms occur. By the same acute observer, a genus of tubicolous Annelids, probably identical with our Serpulæ, was also definitively described*. About this period a useful compilation, under the heads Vermis and Scolopendræ,

* See Supplement to Griffith's edition of Cuvier, vol. xiii.

appeared from the pen of Gesner, presenting a synoptic view of the state of knowledge with reference to this class of animals. The alphabetical order observed by Gesner in the arrangement of the *Vermes*, was violated by Aldrovandus. It is remarked by Cuvier as singular, that to Aldrovandus and his disciples the Chætopoda of Gesner, and the setigerous Annelida of recent observers, should have been unknown; and no less is it to be wondered at, that this writer and his abridgers were unacquainted with the deep differences of zoological characters which separate the slug from the earth-worm—a distinction, too, which Isidore of Seville had already precisely defined—("*Vermis limax dictus eo quod in limo nascitur, unde et sordidus semper et immundus habetur*"). The Chætopoda, or setiferous worms, are however mentioned in the seventh book of Aldrovandus, in allusion to aquatic insects. The Nereids are comprised under the appellation of *Sea-Scolopendræ*. The *Gordius* is called "*seta* vel vitalis aquaticus," and which has been denominated *Gordius* from the habit of twisting itself up like the Gordian knot. The *Ololygon* of Theon appears to have been the same worm. By this author the *Sipunculi* of Rondelet are spoken of as sea-leeches; under the same name are characterized the *Arenicola* of Belon. The epoch of Ray had now arrived, distinguished as it was by a radical regeneration of natural science. In the group *Insecta* of Ray were comprehended all articulate animals: amongst other subdivisions of this class, that of the *Apoda*, including those worms which live in the earth, and that of *Intestinæ*, those which infest the bodies of animals, may be recognised. Under the head *Insecta terrestria*, Ray ranks (the Myriapods) the *true* Scolopendræ; and in his aquatic division of *Insecta*, the Sea-Scolopendræ or Nereids occur. In the first edition of his 'Systema Naturæ,' Linnæus extended the term *Vermis* to all animals except the Vertebrata and Insecta; excluding however the insect-worms of Ray from his class *Vermis*. After this first essay appeared an account of the genera *Amphitrite*, *Nereis* and *Aphrodita*, which belong to the Chætopoda. In the subsequent edition of Linnæus, the name *Intestinæ* was substituted for Reptilia for the first order. In a following edition the class of Worms is subdivided into five orders—*Intestina*, *Mollusca*, *Testacea*, *Lithophyta*, and *Zoophyta*, and the genera which at present constitute the class of red-blooded worms were parcelled out, some as *Lumbricus* and *Hirudo* in the first order; others, as *Terebella*, *Aphrodita* and *Nereis*, in the second; and finally, some, as *Serpula* and *Sabella*, in the fourth, in consequence of the tube in which they live. The true zoological limits of the Annelida were, however, only confusedly determined by the observers of nature antecedently to the time of Pallas (1766). To the sagacity and industry of this naturalist, science is indebted for the first clear definition of the boundaries of this class. By his successful researches on the *Aphroditæ*, the *Nereides* and the *Serpulæ*, a material advance was imparted to the knowledge of the Annelida as a class. He recognised the principle, that the presence or absence of a calcareous envelope did not constitute a sufficient ground for placing in two separate orders animals which in other respects are similarly organized. The *Aphrodites* and *Nereids* of the order *Mollusca* of Linnæus, and the *Serpulæ* and *Amphitritæ* of his order *Testacea*, were accordingly grouped into a single order, through which lay the passage to the Zoophytes. To this order were also annexed the *Hirudines*, *Lumbrici*, the *Ascarides*, the *Gordius*, and the *Tæniæ*. The data thus accumulated by Pallas constitute the foundation of the modern classification of the Worm-tribe.

After this the *Nereids* were made the subject of extensive inquiries by the two Danish philosophers, O. T. Müller and O. Fabricius. By these authors additions were also made to the history of the *Naïdes* and *Amphitrites*.

Blumenbach it was who first observed that true worms are in no instance distinguished by the possession of *articulated* organs of motion, a negative character in which they are separated from all insects and crustacea. Additions to the number of genera at this period were made by Gmelin in his new edition of the 'Systema Naturæ.'

Under the name of *Worms*, Cuvier, in the year 1798, in his Synopsis of Animals, introduces a chapter in which the Vermes of Linnæus are presented under two leading groups, of which one includes those worms in which the setæ or spines for locomotion are present; and the other those in which these organs are absent: thus were first instituted the two orders *Chætopoda* and *Apoda*, a distinction afterwards adopted by M. de Blainville. Cuvier thus followed in the direction first indicated by Pallas, and abandoning the views of Linnæus, returned to the adoption of those of Aldrovandus, Mouffet, and Ray.

Even at this period in the history of invertebrated animals, which afterwards he himself was destined so remarkably to extend, Cuvier saw, though only with dim insight, the necessity of separating the Entozoa (which at the time could be thrown only into a sort of *incerta sedes*) from the true worms. In the year 1802, in a memoir read before the 'Institute' on the organization of the *Chætopoda*, M. Cuvier first proposed to designate this division under the phrase *red-blooded worms*, adding to it the genera *Hirudo* and *Lumbricus*. It was about this time that M. de Lamarck defined with increased clearness the line indicated by Cuvier which divided the *Chætopoda* from the *Intestina*. A new æra in the history of the Annelida was now about to occur, for it was in the year 1812 that the class-name *Annelides* sprang from the fertile and inventive fancy of M. de Lamarck. By this denomination, through various mutations, the Worm-tribe has ever since been known among naturalists.

Nomenclature.—The word *Annelides*, invented by M. de Lamarck, and adopted by M. Bruguière in his excellent article in the French Encyclopædia, by M. de Blainville, by M. de Savigny, and Milne-Edwards, is probably derived from the Latin *annellus*, to which has been affixed the Greek termination *eidos*. It is therefore a compound epithet of illegitimate construction, for the rules governing the formation of new words require that the constituent *etymons* should be drawn from the same language. It is not a purely French word, for the substantive *annelet* is used in French to signify the diminutive of *ring*. It is not a Latin word, for the substantive *annus*, i. e. *circulus*, gives the participle *annulata*, and this is the name which Mr. Macleay has preferred*.

The *Vermes* of Linnæus, then, became the *Vers à sang rouge* of the early editions of the 'Règne Animal': the *Annelides* of Lamarck, Blainville, Savigny, Fleming, Audouin and Milne-Edwards, has settled into the latinized *Annelida* of all English authors on comparative anatomy; a word, however ungrammatical, which has grown into universal and unalterable employment among all modern naturalists.

Zoological position of the Class.—The attempt to allocate animals in a *linear* series from the zoophyte to the mammal has led to many false distributions of classes; nor is it yet manifest that the truly natural principle of arrangement has been evolved out of the wondrously accumulated data of modern science. Neither the nervous nor the circulatory system is available, in the inferior extreme of the scale, as a groundwork of classification. From extended researches on the homology of the nutritious fluids of the Invertebrata recently conducted by the author†, it is certain that below the Echinoder-

* Annals and Mag. of Nat. Hist. vol. iv. p. 385.

† For a full statement of these observations, see Art. PULMO, Cyclop. Anat. and Physiology.

mata no true blood exists, defining the blood as a fluid circulating in a distinctly and independently organized system of vessels. In the Zoophytes and Acalephæ, the blood is replaced by a fluid, the basis of which is sea-water. In the organism of the Echinoderm and the Annelid, notwithstanding the superaddition of a distinct system of vessels for the blood proper, this fluid, the characters of which will be afterwards described, constitutes an *organic* zoological character more significant of *locality* in the series than any other single element of structure. Guided by the affinities of this important fluid, the naturalist may discover unquestionable points of serial approximation between the Annelid and Echinoderm through the *Sipunculidæ* on one side; at another angle of the group, the *Aphrodita aculeata* exhibits the most striking resemblance in structure (the mere outward form excepted) to the *Asteridæ*.

In another direction the Annelida approach the inferior Mollusca. Many features of analogy exist between the Tunicata and the Echinodermata through the genus *Pelonaia*, which in its general form and in some structural characters betrays an obvious tendency towards the *Sipunculidæ*, whilst in other respects in that group an undoubted approximation is traceable to the annulose division, in the appearance of a disposition to bilateral symmetry in the packing of the viscera and the transverse segmentation of the external tunic. Among the Gasteropod Molluscs, as originally indicated by Milne-Edwards*, an approach is made through the Chitons in the direction of the annulose families. It was M. de Blainville, however, who first suspected this alliance, and accordingly constituted a special group, transitional between the Mollusca and Annelida, under the name of *Polyplaxiphora*. In the transverse segmentation of the shell of the Chitons, a remarkable resemblance is offered to the covering of an articulated animal: nor is this resemblance limited to the shell, for its several parts are connected together by means of a complex muscular apparatus, which enables the animal to move them one upon the other in such a manner as to roll itself up into a ball: nor are there wanting other similarities of external structure; the generative apparatus presents a symmetrical arrangement after the type rather of that of the Annelid than of that of the Mollusc. The heart occurs under the character of a pulsatile dorsal vessel, indicative of another affinity to the Annulosa. In the *Chitonellus* the tendency to the transverse division of the body is still more significantly marked. Here the shell is not sufficiently developed to cover the dorsum of the animal, yet its several rudimentary pieces are disposed at regular intervals like the scales of the Aphrodite; the vermiform elongation of the body is more decided, and the circulating system is still more obviously constructed on the plan of that of the Annelid. The respiratory and digestive organs, and the lingual apparatus on the other hand, remind us, as suggested by Prof. Forbes, of the corresponding organs of the *Prosobranchiate* Molluscs, while the creeping disc is that of a true Gasteropod.

It is a subject of surprise that the *Dentaliadæ*, the molluscan nature of which is now so conclusively established, should have received, in the last French edition of the 'Règne Animal†,' a place among the tubicolous Annelida. The researches of Deshayes and Savigny, and more satisfactorily those of M. de Blainville and Mr. Clark‡, have abundantly proved that these

* Mem. on the Classification of the Gasteropoda, in Ann. des Sci. Nat. Ser. iii. Zool. vol. ix. p. 102.

† This is by far the most perfect and elaborate edition of this great work ever published, the editorship of which has been conducted by the disciples of Cuvier. It is known as Crochard's Edition.

‡ See Annals of Natural History, Nov. 1849.

Gasteropods should rank somewhere between the *Chiton* and *Patella*. In *Dentalium*, the symmetrical subventral position of the branchiæ, the posterior flow into them of the water, and the resemblance of the foot to that of some of the bivalves, appear in a striking manner to prove its connection with the Conchiferæ; whilst by its œsophageal cerebral ganglions, and the completeness of its circulating system, its affinity to the Gasteropod is established. But it cannot be disputed that there are, on the other hand, evidences of approximation to the Annulose tribes; the *red blood*, and the vermiform configuration of the posterior part of the body, the tubular figure of the shell, the operation of the operculum, the apparent resemblance of the branchiæ to those of the *Sabellæ*, may be readily conceived as prefiguring some of the outward features of the Annelida. These points of analogy however are merely apparent and superficial; the *Dentaliadæ* are therefore hereby excluded from the pale of this Report.

Both Cuvier and Lamarck saw in the Cyclostomatous fishes indications of resemblance to the Annulose tribes. In the anatomy of *Amphioxus* there exists only one fact of structure which likens it to the Annelid. The circulating system consists of two longitudinal trunks, a dorsal and ventral; the movement of the blood, however, being the exact reverse of that of the Annelids; the current in the dorsal vessels sets in the direction of the tail, that in the ventral forwards! The affinities of the *Amphioxus*, indeed, connect it much more intimately with the Ascidian Mollusk than with the Annelid.

The data to be advanced in the subsequent portions of this Report will prove that a much closer analogy exists between the Annelida and the Entozoa than that which is implied in the received divisions of systematic naturalists. It will be shown that in every detail of organization the Cestoid Entozoa link directly with the genera *Borlasia* and *Lineus*, both of which rank in the family of the *Planariæ*. The disposition of the intestine, the peculiar situation of the chylo-aqueous fluid, the curving of the intestine as in the *Sipunculidæ*, the corpuscles of the chylo-aqueous fluid in these latter marine worms, establish between them and *Tænia* an immediate relationship. But the author has proved that in the *Planariæ* the cæcal ramifications of the digestive system are *not*, as taught by Owen and all other comparative anatomists, *adherent* to the parenchyma of the body; for a fluid, rendered visible by moving corpuscles, intervenes and is set in motion as in the Echinoderms by vibratile cilia. This fluid, of which much more will hereafter be stated, exists also in the Cestoid Entozoa, and suggests doubts as to the propriety of the nomenclature of Prof. Owen, in which they are characterized as *solid-worms*, or *Sterelmintha*.

In the Nematoid Entozoa, the space between the intestine and integument is more capacious and filled with a much larger amount of that fluid, which in this Report it is proposed to distinguish under the name of *Chylo-aqueous fluid*. This division of the Entozoa is denominated by Professor Owen the *Cœlelmintha* or *cavitary worms*.

Notwithstanding the recent excellent researches of M. Blanchard*, the difficulties raised by the investigations of the author of this Report on the structure of the allied genera of Annelida, will demand a re-examination of the whole class of Entozoa. Impressed at present in a strong manner with the conception of the essential unity of the type on which the Entozoa and Annelida are constructed, we applaud the caution and doubt with which Professor Owen† speaks as to the place in the zoological series in which the Entozoa are made at present to stand. "These animals are associated together chiefly in consequence of a similarity of local habitation, which are the internal parts

* Ann. des Sci. Nat. 1849.

† See Art. *Entozoa*, Cyclop. Anat. and Physiology.

of animals. In treating therefore of the organization of these parasites, we are compelled to consider them, not as a class of animals, established on any common, exclusive or intelligible characters, but as inhabitants of a peculiar district or country." In the progress of this Memoir it will be rendered indisputable, that if the 'denominations' established by the learned Hunterian Professor among the Entozoa be applicable and rightful on the ground of anatomical structure, the same terms, on the same plea, will become available in the methodical distribution of the Annelida. Anatomical inquiries afford no sanction to the use of these phrases: There is *no solid* annelid, neither is there a *solid* Entozoon.—Why then perpetuate the employment of terms productive only of false conceptions? Difference of habitat neither suggests nor requires a corresponding difference of organization: species of the same genus, and nearly allied, are frequently found to maintain existence under very diverse physical conditions. The inference is, therefore, even *à priori* probable and just, which demurs to the separation of the Entozoa from the Annelida on the ground of a difference in the outward circumstances of existence; nor is the propriety of such division yet clearly sanctioned by the evidence drawn from anatomy. There is no single trait by which the separation is so much justified as in that of the absence in the Entozoa of the transverse annuli so characteristic of the true annelid.

From these observations it must be evident, that the interposition, as has been done by Dr. Carpenter*, of the Rotifera between the Entozoa and Annelida, can only be regarded as the putting asunder, on hypothetic principles, those whom nature has intimately united in the bonds of consanguinity.

Surveying the Worm-class in its affinities to those, superior to the Annelidan standard in the scale, the eye encounters the highest forms of the articulate type. In the structure of the Annelida and the Myriapoda, marks of a community of plan may be readily discerned. The leech and the earth-worm on one side, and *Iulus* on the other, occupy the verge of the frontier-line dividing these two articulate families. Neither the leech nor the earth-worm is provided with any special organs for atmospheric respiration. The so-called *respiratory sacculi* have nothing whatever to do with the respiratory process; and though from the date of the early Essays of Dugès to the present time, they have received the fondest marks of attention from every succeeding anatomist, as beautiful evidences of design, fitting these humble worms for the double luxuries of an amphibious life; to these parts, henceforth, must be assigned a far different function.

It is only in this particular that the leech and the earth-worm, whose organization is singularly similar, stand distinguished from all other Annelida; that in them, more especially in the leech, the intestine is so uniformly adherent to the integument as to preclude the existence of the chylo-aqueous fluid. The intestine is joined to the integument by means of a thick spongy layer, blended intimately with pigmentary epithelium, and composed of capillary blood-vessels. *This* is the true apparatus of respiration, and the mechanism of its function will be afterwards explained. The general proposition may here be enounced, that, in all Annelids, the true blood system and that of the chylo-aqueous fluid are *inversely* proportional to each other. The greater the amount of the latter, the less the complexity of the former, and conversely. In the leech the peripheral circulation is densely complex, and the chylo-aqueous fluid is superseded. In the earth-worm the latter fluid is present in small amount, and the proper blood system is, in this proportion, less elaborately developed. Between these two important systems of nutritious fluids, there exists in the economy of the Annelida a wonderful

* See Principles of Physiology, 1851.

physiological balance; it is a subject which conducts to a new path of inquiry. The problem of organization in the Echinoderm, Acalephæ and Zoophytes, through aid of its suggestive guidance, will soon receive a new solution.

From the researches of Mr. Newport it appears that the series of lateral respiratory sacculi (*sic*) already described in the leech and the earth-worm, are also present in *Iulus*. This fact, more than any other, serves to demonstrate a near zoological relationship between this myriapod and the Annelida. In the tendency to segmental repetition in the body, in the history of the development of the embryo, and in the character and distribution of the main vascular trunks, the *Iulidæ* exhibit a close similarity to the Annelida. As the *Iulidæ* differ from insects in the absence of wings, they no less strikingly differ from the Annelida in the possession of articulated members.

The true classification of articulate animals can only be reached through the joint aid of comparative anatomy and embryological metamorphoses. In the latter department Agassiz has done much*. These two methods lead, however, to different results. By the naturalist it has been considered that the presence of a heart in Crustacea entitles this class to the highest place among the Articulata. This arrangement is founded upon the view that all animals should form a natural linear series, disposed in one progressive line according to their successive gradations of structure. The distinction introduced by Cuvier of different types, of four distinct plans of structure, has not yet sufficiently penetrated the spirit of those who have followed in his steps. Viewed thus as separate types, it is evident that what might be regarded as a character of superiority in one group, may not be entitled to such consideration in another; that in each type a separate ruling principle should be recognised, and that these types could not be brought into connection with each other unless upon the most general considerations.

The embryo of the Annelid undergoes few, if any, metamorphoses. It is true that the young are at first almost wholly devoid of appendages; but the body in no instance suffers those deep transmutations traceable in the growth of the larvæ of Insects and Crustacea. A considerable change of outward form is impossible, without some mutation of structure. Embryological metamorphoses accordingly become grounds of comparison and induction in the eye of the systematic zoologist. As the metamorphoses of an embryo by which it is raised to its *mature* phase cannot be held, at all events, as retrograde steps in organization; it is not difficult to perceive that these 'changes' from the ovum to the perfect animal may lead to valuable inferences as to the real and final place of the adult animal in the series. Now, since the insect reaches the standard of the annelid in its first metamorphose (the vermiform caterpillar), its ultimate destination, after two further mutations, must place it far above the rank of the worm. It cannot be doubted that a comparison, instituted between the larval conditions of Insects generally and the Annelida, would issue in many interesting discoveries: such comparative view has actually led M. Agassiz to see in the naked larvæ the prototypes of the non-setigerous or Abranchiate Annelids,—and in those provided with appendages a resemblance to the dorsibranchiate and cephalobranchiate worms. Nor does this distinguished naturalist scruple to descend to particulars in this comparison, declaring that the larvæ of *Simacodes* may be viewed as terrestrial representatives of the genus *Polynoë*; those of *Bombyces* as corresponding to the *Nereids*; while some among the larvæ of *Papilio* proper, with their protractile branching appendages upon the neck, remind us

* "Classification on Embryological Data," Trans. of American Association for the Advancement of Science, 1850.

of *Terebella.* The same line of argumentation applied to the Crustacea has led this naturalist to infer that this class should occupy a place immediately above the Annelida and *below* Insects ; that thus the Annelida should stand at the bottom of the *Annulose* series and the Insecta at the summit, the Crustacea being intermediate.

While we are willing to applaud the sagacity of these speculative thoughts, we must persist, in this Report, in adhering to the evidence drawn from *adult* rather than embryonic structures, and that on the plea that mature forms in the *same* sub-kingdom must bear to each other constant and invariable relations, and that the perfect animal no less than the transfigurations of the embryo, by the deep written characters of its organism, must attest its true relative position. It will accordingly be maintained in this memoir, that *below*, the nearest connection of the Annelida are the Entozoa ; that the *Sipunculidæ* associate them in a direct and natural manner with the Echinoderms, and with far greater intimacy of resemblance in structure than that with which they are joined to the Mollusca by the intervention of the *Chitonidæ*, and that above the Annelida should be placed the inferior species of the *Iulidæ*. Considerations founded on anatomical evidence will be afterwards advanced confirming the propriety of this distribution.

It is proposed now to enter at some length upon that division of our Report which relates to the anatomy of Annelida, as an appropriate prelude to a detailed study of species.

Anatomy of the Annelida.—Anatomical details, correctly determined, will be found hereafter indispensable to the classification of the Annelida. These animals, unlike all other inferior tribes, in many instances present so little external diversity among themselves, while their internal organization at the same time may be strongly marked by specific peculiarities, that a careful consideration of the anatomy of the class will here appropriately precede that of its methodical arrangement. Certain leading points in the structure of worms were established by the dissections of the earlier anatomists. The researches of Willis* gave some rude conception of the character of the circulation of the blood, and the outline of the alimentary system. By Sir E. Home† this inquiry was prosecuted to some further extent ; and in this path of investigation, this comparative anatomist was followed by M. de Blainville‡ and Morren§. It was about this date that the labours of M. Dugès were given to science, by the publication of his memoirs on the circulation and reproductive system of the Annelides‖. It is a fact lamentable to relate, that the errors and imperfect dissections of the professor of Montpellier should have been propagated through the classic works of the most distinguished modern authors down to the present time. The account which M. Dugès has given of the reproductive organs of the leech and the *Nais* is full of grave errors, and it will be afterwards proved that those of M. Quatrefages, although nearly fifty years later, are little less remote from the truth of nature. It should have been previously stated, that in the year 1806 a M. Thomas¶ had already thrown some light on the anatomy of the leech. The 'Leçons d'Anatomie Comparée' of Cuvier, edited by M. Dumeril, which appeared about this period, on the subject of the anatomy of the Annelida, contained little more than an epitomized statement of what had been previously published.

* De Animâ Brutorum. † Philosophical Transactions.

‡ Dictionnaire des Sciences naturelles, t. lvii. p. 407.

§ De Lumbricibus terrestribus historia naturali necnon anatomia tractatus. Bruxelles 1829.

‖ Recherches sur la circulation, la respiration et la reproduction des Annelides abranches. Annales des Sciences naturelles, 1re Série, t. xv. 1828.

¶ Mémoire pour servir à l'histoire naturelle des Sangsues, in 8vo, Paris 1806.

The names of Moquin-Tonquin of Montpellier and M. Philippi of Milan*, should be honourably associated with this branch of comparative anatomy. Hunter had formed a correct appreciation of the general structure of several species of Annelids, as exemplified in the beautiful preparations which he has bequeathed to the science, in the Hunterian collection†. The organization of the *Serpulæ*, the *Amphitritæ*, and *Nereidæ*, have been meritoriously studied by M. Delle Chiaje‡.

The researches of the earlier English zoologists were for the most part limited to the descriptive history of species; the names of Leach and Montague should, notwithstanding, be gratefully allied with this department of natural science in England. Dr. George Johnston of Berwick-on-Tweed has done more than any other modern observer to rescue the Annelids from the region of obscurity and confusion. The descriptions of this excellent naturalist are characterized by exactness and truth, and his investigations of structure, as far as they have extended, seldom deviate much from the results attained through aid of the modern microscope§.

It is scarcely required to remark, that the efforts of ancient anatomists, however laborious, in those fields especially in which the subjects of investigation were minute in size and of difficult manipulation, anterior to the era of the microscope, could at best have been but imperfect. In the preparation of this memoir, it will be accordingly found that the author will have few acknowledgements to render to the works of these venerable authors. This observation, however, does not apply to the labours of Owen and Milne-Edwards, by whom, indeed, almost everything hitherto known to science with reference to the organization of the Entozoa and Annelida has been contributed. The researches of Milne-Edwards have been principally confined to the system of the circulation in the Annelida‖; those of Prof. Owen are restricted to the Entozoa¶. The author of this Report desires in this place to bear testimony to the accuracy of the observations of Milne-Edwards. His account, however, as stated, embraces little more than the *central* apparatus of the circulation, and yet it will be subsequently seen that the study of the characters of the *periphery* of the circulation, identified as it must be with the intimate structure of the integral organs of the body, will conduct to results of the highest interest. The author regrets that it has not been in his power to refer in any satisfactory manner to the recent works of the Swedish and Danish naturalists on the subject of the Annelida. The reports by Prof. Siebold of Erlangen, published by the Ray Society, are very insufficient for the purposes of reference; nor are all the anatomical investigations of M. de Quatrefages and M. Blanchard within reach.

The Circulating Fluids.—In the economy of *all* Annelids, one or two species excepted, two distinct and separate fluid elements of nutrition exist; of which one consists of the proper and true blood, contained in closed vessels and moving in a definite orbit, and constituting a well-marked *circulation*; the other of a liquid mass, filling the open space which, in all species, intervenes between the intestine and the integument, holding organic corpuscles

* Memoria sugli Annelidi della famiglia delle Sanguisughe, in 4to, Milan 1837.

† Descriptive and Illustrated Catalogue of the Physiological Series, &c. by Owen, vol. ii.

‡ Memorie sulla storia i uotomia degli Animali senza vertebre del regno di Napoli, tom. ii. and iii.

§ The contributions of Dr. Johnston to this branch of natural history will be found distributed throughout the early series of the 'Annals and Magazine of Natural History.' In treating of species, separate references will be made to this author's publications.

‖ Recherches pour servir à l'histoire de la circulation du sang chez les Annelides, lues à l'Académie des Sciences, le 30 Octobre 1837.

¶ Art. *Entozoa*, Cyclopædia of Anatomy and Physiology.

in suspension, varying in different species, and performing irregular to and fro oscillations under the agency of the muscular contractions of the intestine and integuments. On these two fluids, two separate physiological functions devolve: each is essential to the maintenance of life in the Annelid; nor is it improbable that the clue unravelled by the study of these fluid elements in this class, will lead to important conclusions in relation to the mechanism of nutrition in all invertebrate animals. All the recesses and ramifications of the *general cavity of the body* in the Annelids, communicate freely with each other, constituting thus one common space. This cavity is lined by a distinct membrane, which is obviously the anatomical analogon of the *peritoneum*, and is filled by a fluid which is unquestionably an organic fluid. Reasons will be afterwards adduced for regarding this fluid as physiologically allied to the chyle of the higher animals, and the containing cavity as the prototype of the *peritoneal*. It is therefore proposed in this memoir to distinguish this general splanchnic chamber as the *peritoneal cavity*, and the contained fluid under the designation of the *peritoneal fluid*, or the chyle-aqueous fluid of the peritoneal cavity. In the Annelida, the peritoneal membrane is *not vibratile*; the oscillations of the fluid contents cannot therefore be due to ciliary vibration. This fact distinguishes the Annelid from the Echinodermata, of which the peritoneal space, in *all* species, even in the *Sipunculidæ*, is richly lined with vibratile cilia. This observation it is only necessary to qualify by the single remark, that in *some* species of Annelids, as that of *Glycera*, the hollow interior of the *branchiæ* in which the peritoneal circulates *is* lined with mobile cilia.

The real characters of this fluid have remained up to the date of the researches of the author of this Report quite unknown to anatomists*.

* About two years ago he communicated to the Swansea Literary and Scientific Society a paper "On the Structure and Habits of the Annelida," in which a summary was presented of the results at which he had then arrived, with respect to the organic and chemical composition of this fluid. In that communication, illustrations of the floating organic corpuscles were also exhibited, and the views, expounded in the text, with regard to the physiological signification of the fluid in the economy of the worm, were first sketched. The author has only recently become acquainted with a memoir, "Sur la famille des Hermelliens," by M. De Quatrefages (Annales des Sciences Naturelles, 3me série, 1848), in which this industrious French anatomist alludes in the following language to the general cavity of the body in the instance of *Sabella alveolata*:—

"Chez les Hermelles comme chez toutes les Annelides, et on peut le dire aujourd'hui, comme chez la majorité des invertébrés, les teguments et les couches musculaires sousjacentes circonscrivent une cavité, dans laquelle est renfermé le tube digestif. Dans les Annelides en général, dans les Hermelles en particulier, cette cavité n'est pas d'une seule venue. Entre chaque anneau se trouvent des cloisons incomplètes formées par des colonnes musculaires qui s'élèvent en s'élargissant, et se soudant de bas en haut, de manière à former en dessus une membrane. Entre le dernier anneau thoracique et le premier anneau abdominal, la cloison est beaucoup plus épaisse et plus complète; elle manque, au contraire, entre le deuxième, et le troisième anneau abdominal, espèce qui correspond au jabot. Dans chaque anneau de l'abdomen considéré isolément, la cavité renferme une portion du tube digestif et des organes genitaux. Sur les côtés, à la hauteur des pieds, cette cavité se prolonge dans l'intérieur de ces derniers. Les gaînes des soies, les muscles qui les mettent en mouvement, sont entièrement libres dans ces espèces des chambres. La couche de tissus très délicats qui tapisse l'intérieur des pieds est hérissée de grands cils vibratiles. Le mouvement de ces cils est loin d'être régulier et constant; on le voit quelquefois régner dans toute l'étendue de la cavité; d'autres fois s'arrêter entièrement; mais le plus souvent, il est partiel, et se manifeste tantôt sur un point, tantôt sur un autre. Malgré le nombre d'observations, très considérable que j'ai faites sur des Annelides errantes ou tubicoles, c'est la seconde fois seulement que j'ai rencontré des cils vibratiles dans une dépendance de la cavité générale du corps. A l'époque de la reproduction, la cavité dont nous parlons est remplie par les œufs ou les spermatozoïdes, qui pénètrent jusque dans l'intérieur des chambres des pieds. En temps ordinaire, on trouve dans la cavité générale un liquide parfaitement incoloré, au milieu duquel nagent des corpuscules irreguliers refractant fortement la lumière, et dont le nombre varie dans les divers indi-

The coagulating principle consists of fibrine, and there can be no doubt that the great bulk of the fluid portion is composed of sea-water. The morphotic elements vary in a remarkable manner in different species; that is, for the *same* species the corpuscles of the peritoneal fluid are constant, and *nearly* the same for every season of the year. In different species, therefore, these solid elements become signs of specific distinction, but the *specific* variation is much less marked than the generic; this is exemplified in the instances of the *Spios* and *Terebellæ*. In *Spio coniocephala* these corpuscles are large flattened oval cells, enclosing smaller elliptical bodies and a nucleus, and presenting a singularly serrated border. (Plate II. fig. 1.) In *Spio vulgaris*, a smaller species of the same genus, the same bodies occur under a reduced size; the serrated edges, however, are still observed. The serrations are not endowed with any motive property, for these cells manifest no locomotive power. The *ova* of these same Annelids are orbicular, nucleated bodies, and differing strikingly from the serrated corpuscles just described; these latter are *always* present in the peritoneal fluid; the ova are very seldom to be found. These facts, which are readily and demonstratively established, prove beyond doubt that the serrated bodies are *not* germ-cells. The illustrations present them in the maturity of growth; they never attain a larger size. In two species of *Terebella* which abound on these coasts, the peritoneal fluid contains morphic elements of a similar character, and no less specifically peculiar.

These bodies, in *Terebella nebulosa*, the larger of the two species, are *smooth-edged* oval cells, slightly compressed, containing six or seven or more oil-globules, highly refractive, and filled with spherical molecules, floating in a fluid possessing a refractive power greater than that of the outer fluid (Plate II. fig. 2). In these bodies no nucleus is discoverable, a fact which clearly distinguishes them from true *ova*.

They are commonly however mistaken for ova in this species, and the peritoneal chamber is accordingly described as a marsupium or incubating cavity; additional proofs will be afterwards adduced of the fallacy of this conclusion. In this species, other bodies than those described floating in the peritoneal fluid may be seen; these latter consist of spindle-shaped and irregular cells, fragments of cell-membrane and other compound bodies, all differing from the regularly oval cells which constitute the bulk of the solid elements of the fluid. The spindle-figured bodies, especially when affixing themselves at one extremity into a stellar bunch, may be readily mistaken for sperm-cells, with which, however, on other grounds, they are not to be

vidus." From this passage it is evident that Quatrefages has done little more than recognise the existence of a fluid in the general cavity of the body. It is true, as explained in the author's Report, that in some species ova and spermatozoa are sometimes found floating in this fluid. But it is not in accordance with his observations that this fluid is kept in motion by *cilia*. In no single species are these internal cilia to be found in the general peritoneal cavity. It is easy to mistake those which in many species clothe the bases of the feet and branchiæ *externally*, for the agents occasioning the motion of the fluid in the *interior*. Quatrefages says nothing of the composition of this fluid, of its uses in the economy; he makes no allusion to the specific differences which the floating corpuscles exhibit in different species, nor does he appear to have suspected any connexion between this fluid and the true blood contained in the blood-vessels. The merit of priority in the demonstration of the composition, and in the appreciation of the physiological significance of the peritoneal fluid of the Annelida, is therefore claimed for the author of this Report.

It is only possible in the larger species to obtain it in sufficient quantity for *chemical* analysis. In *Terebella nebulosa*, *Arenicola*, and the large Nereids, it may be readily collected for examination. It is denser in gravity than common sea-water.

In a few minutes after removal from the body of the animal, it throws down an unquestionable coagulum, like the clot of true blood. The organic corpuscles cohere into groups and masses, and sink with the clot.

confounded. In *Terebella conchilega*, a species very closely allied to the former, but inferior in size, the corpuscles of the peritoneal fluid consist of cells of precisely analogous organization. Like the corresponding bodies in *Terebella nebulosa*, they are regular and uniform in figure, size and structure. Such remarkable uniformity proves incontestably that they are governed by a definite law of parentage, birth and growth; that they are restricted to determinate dimensions by a singularly invariable principle of increase. In these two species the cephalic cirrhi or tentacles are composed of hollow tubes, filled with the peritoneal fluid; the movements of this fluid are determined by the muscular walls of the containing cavity; the tentacles are extended and contracted by the alternate flux and reflux of this fluid in their axes. In the general cavity of the body it is urged to and fro in large waves by muscular agency, and not by ciliary. Mechanically and physiologically, this fluid is immediately essential to the maintenance of life; mechanically, by preventing contact between the intestine and integument, thus favouring the circulation of the blood-proper; and physiologically, by furnishing the pabulum out of which the latter fluid is perpetually being reinforced.

In other species this fluid is characterized by equally distinctive peculiarities. In *Arenicola Piscatorum* it is abundant, and highly charged with corpuscles. Towards the month of August it increases in amount by the influx of oviform bodies, but at every season it abounds in corpuscular elements, which consist of compound granular cells, from the circumferences of which digitate and filiform processes project, imparting to the cells an appearance resembling that of spermatozoid bodies; the oviform corpuscles are spherical, and distinguished at some point of their circumference by a bright, pellucid, nucleated cell. It will be shown in another part of this memoir, that although these bodies severally resemble the sperm- and germ-cells of this Annelid, yet general analogy requires that they be regarded as peculiar to the peritoneal fluid (Plate II. fig. 3).

In the earth-worm the space between the intestine and integument is almost obliterated, these two cylinders being so closely bound to each other at the interannular bands. There exists, however, in the chambers between these dissepiments a small quantity of viscid fluid, the morphotic elements of which consist of uniformly figured spherical molecules, bearing a few granules, and in some instances a nucleus. The *true ova*, which in this familiar Annelid can be proved *never to enter the peritoneal cavity*, are perfectly distinct from these corpuscles; these latter being manifestly *peculiar* to the peritoneal fluid, another datum corroborative of the view which regards this fluid as fitted to discharge functions independent of the reproductive. In the *Onone maculata* the fluid is thickly charged with minute orbicular particles, all of the same size and figure, and very minute, and bearing no analogy whatever to the ova of the same worm.

The *Borlasiæ* and *Liniadæ*, of the family *Planariæ*, present a plan of structure which distinguishes them in a very marked manner from other orders of Annelida. The œsophageal intestine, turned upon itself, terminates here not far from the cephalic extremity of the body, after the manner of that of the *Sipunculidæ*. A hollow sacculated organ then proceeds from the base of the proboscis throughout the body as far as the tail. By Quatrefages, Blanchard and Milne-Edwards, this remarkable organ has been mistaken for the ovarian system. It is, however, a true alimentary system, and it is in *its* cavity in these species that the peritoneal fluid is contained, and not in the space, which in these instances is obliterated, between this organ and the integument. The corpuscular elements consist here of fusiform and ellip-

tical cells, transparent and devoid of granular contents, and quite dissimilar in character from the true ova.

In the genus *Sabella*, the peritoneal fluid is opalescent and thickly corpusculated; it does not change its colour with that of the true blood, since its colour is the same in those species which are distinguished by *green* blood as in those of which the blood is red. The bodies in this instance consist of several varieties of cells, some of which are fibre-like, others orbicular, and bearing granules; but in different individuals of the same species *they are constant*. In the Nereids (fig. 4) these corpuscles are more or less oviform, and the fluid is distinct, but not large in quantity. In the *Aphroditaceæ* it is charged with epithelium-like scaly bodies. To this remark the *Aphrodita aculeata* is an exception, for here the fluid bears no visible morphous substances, and seems to depart little from the standard of salt water. In one other respect this aberrant Annelid approaches the Asterias; namely, in the fact that the peritoneal cavity is *lined* by vibratile epithelium.

It must not be overlooked, however, that in this Aphrodite the alimentary system exhibits a curious modification when considered in relation to the plan prevalent among the Annelida as a class. The chylous fluid in this case is transferred from the outside (peritoneal cavity) to the interior of the digestive cæcal processes, from which it is absorbed into the system of the blood-proper; the exception therefore becomes more apparent than real. No example occurs in the whole class in which the real physiological character of this peritoneal fluid becomes so unequivocal as in that of *Glycera alba* (fig. 5). The general cavity of the body in this beautiful worm is filled with a fluid, bearing in great abundance *blood-red* flattened oval corpuscles, resembling the blood-corpuscles of the frog. *This is the only Annelid in which the bodies of the peritoneal fluid are coloured.* The blood-proper in this species is almost devoid of colour, faintly red, and quite incorpuscular. The bases of the feet in this worm, as in many others, are hollow, and the branchial processes are tubular and filled with the peritoneal fluid, the interior being lined by vibratile epithelium. The branchial process, which is lined within and without by vibratile epithelium, is filled with the peritoneal fluid, the corpuscles of which move under ciliary agency, peripherally along one side, and centrally along the other of the process. The walls of this appendage contain no true blood-vessels; and there exists no other respiratory organ. The inference is therefore irresistible, that the peritoneal fluid it is, and *not* the blood-proper, which in this case is submitted to the influence of the aërating medium; and the branchial process exhibits a structure modified with express reference to the efficient exposure of *this* fluid rather than of the blood. These facts lead by obvious induction to the two-fold division of the process and mechanism of respiration in the Annelida, that, first, in which the true blood is submitted directly to the process of aëration; and that, secondly, in which the peritoneal fluid is the medium which immediately receives the external oxygen. The system for the circulation of the blood-proper under the latter circumstances is little developed; under the former it is more elaborate, and the volume of the peritoneal fluid is proportionately reduced. There is observable, then, both physiologically and anatomically, an inverse relationship between these two systems of nutritious fluids. It follows further from the facts, which, in the example of *Glycera alba* are so easy of demonstration, that if the peritoneal fluid, which is so unquestionably the recipient, be the reservoir for the collection of the external oxygen, and consequently of carbonic acid from the blood-proper, the interchange of gases between it and the external sea-water could not occur if *both* were of the same specific gra-

vity. This is an inferential datum, which proves that the peritoneal fluid, although consisting *of a large proportion of sea-water, is notwithstanding an organic fluid.* This fluid, in the instances of the *Terebellæ* and *Arenicola*, in which it is abundant, is rendered opake by the addition of nitric acid, proving the presence of albumen; and by standing, a coagulum is formed, sufficient to prove the presence of fibrine; and the microscope establishes the existence of highly organized compound corpuscles.

Now, that the basis of this fluid consists of sea-water, is rendered almost certain by the following simple expedient:—If the peritoneal fluid of *Arenicola* or *Terebella nebulosa* be collected in adequate quantity and carefully filtered, and the clear liquor be then submitted to evaporation, the crystalline products will be found identical with those resulting from the evaporation of simple sea-water. The inference then is probable, that the fluid bases of the peritoneal fluid in all Annelida must consist chiefly of sea-water; nor does inductive caution here forbid the generalization suggested by the preceding facts, that in the lower forms of life *the surrounding medium is assimilated with remarkable rapidity*; that sea-water under such circumstances readily assumes the character of an *organic fluid*; in other and more specific language, that sea-water is *vitalized* with wonderful facility by the solid organic elements contained in the peritoneal fluid. It is perfectly impossible to demonstrate any direct communication between the peritoneal cavity and the exterior. The channel of communication lies through the alimentary canal; the water is swallowed, and under the agency of the intestinal, glandular and vascular systems, it receives the first impulse to organization; thence it probably passes by direct transudation into the general peritoneal chamber. The anterior extremity of the intestinal canal is endowed with the power of readily absorbing this fluid, while the caudal end no less readily gives it exit into the rectal division of the same canal; and this is the mechanism by which the peritoneal cavity is supplied with its fluid contents. Whether the peritoneal fluid is organically capable of maintaining the nutrition of the solid structures of the system, cannot be directly proved; but it is scarcely susceptible of doubt, from the intricate manner in which the true blood-vessels coil in the midst of the fluid contents of the general cavity, that the former must absorb from the latter the elements from which the true blood is afterwards manufactured; that in fact it presents the same relation to the contents of the proper blood-system of vessels, as the chyle of the higher animals does to the true blood; the peritoneal fluid of the Annelid differing from the chyle of the mammal only in the fact that the latter is contained in vessels, while the former rolls in a capacious chamber.

The absorbent power of the peritoneal fluid for oxygen is increased in proportion as its density is increased; this property the author deduces from his experiments on salt water. When this fluid is evaporated to different degrees of density, and allowed to stand for a day or two, the gases extricated by boiling bear a direct proportion in volume to the specific gravity. Liebig has recently shown that the absorbent property of water for carbonic acid is very much increased by the addition of phosphate of soda, or a solution of sulphate of copper saturated with nitric oxide. These and analogous facts render the inference highly probable, that the peritoneal fluid, in virtue of its augmented absorbent power, readily withdraws oxygen from the circumfluent medium, and brings this vitalizing gas in a more condensed and concentrated form into immediate contact with the true blood and the solid structures of the body. This mechanism therefore, so far from diminishing, actually multiplies the aërating influence of the surrounding medium. The respiratory process is rendered not less, but more efficient, by

the interposition of the peritoneal fluid between the blood-proper and the external medium.

The history of the remarkable fluid element of nutrition, as now described in the Annelida, will henceforth enable the physiologist to understand how intimately and immediately necessary to the maintenance of the vital actions, the influence of the surrounding medium must be in these inferior orders of animals; how instantaneous the death when transferred into fresh water, and how important the part must be which the mineral and saline ingredients of sea-water perform, in preserving the integrity of the voluminous organic fluids of the body.

Blood-proper.—When Cuvier first constituted the Annelida into an independent class, he attached great importance to the discovery of red blood in these animals, and this fact became the ground of his classification: "Frappé de la couleur si remarkable du liquide nourricier, chez ces animaux, il les désigna d'abord sous le nom de Vers à sang rouge." Lamarck, no less than Cuvier, was impressed with a sense of the important significance of red blood in the animals to which he now applied the name of *Annelides*; like Cuvier, he viewed the red blood as the essential distinction of the class*.

M. de Blainville now discovered that in *Aphrodita Herissa* the blood was *colourless*†. Pallas, however, had in fact anticipated both Cuvier and De Blainville in this discovery, and also in that of the existence of red blood in the Annelida generally‡.

To the laborious researches of Milne-Edwards, the zoologist is indebted for a full and complete history of the *colour* and distribution of the blood in the Annelida§. But it is a remarkable circumstance that so searching an observer should have overlooked the question affecting the microscopic characters of this fluid. After stating that in the *Eunicidæ*, *Euphrosinidæ*, *Nereidæ*, *Nephthys*, *Glycera*, *Ononidæ*, *Arenicola*, *Hermellæ*, *Terebellæ*, *Serpulæ*, *Lumbricus* and *Hirudo*, the blood is of a red colour, he remarks, "Mais, du reste, examiné au microscope, ce liquide ne m'a pas semblé différer du sang des autres animaux sans vertèbres. Les globules qu'on y voit nager n'ont pas du tout l'aspect de ceux propres au sang des animaux vertébrés: ce sont des corpuscules circulaires dont la surface a une apparence framboisée, et dont les dimensions varient extrêmement chez un même animal."

In the passage cited, this eminent author admits the existence of circular corpuscles in the blood of the Annelida, which according to his account present the appearance of raspberries, varying much in dimensions in the same individual‖. In his excellent memoir in the Philosophical Transactions¶,

* "Ce qui a effectivement paru très singulier, ce fut de trouver que les Annelides, quoique moins perfectionnés en organisation que les Mollusques, avaient cependant le sang véritablement rouge, tandis qui dépend de son état et de sa composition, et qui est celle du sang de tous les animaux vertébrés. On sent bien que, parmi les animaux que nous rapportons à notre classe des Annelides, ceux qui si trouveraient n'avoir pas dans leur organisation le caractère classique, n'infirment point ce caractère et ne sont placés ici qu'en attendant que leur organisation soit mieux connue."—Lamarck, *Animaux sans Vertèbres*, t. v. p. 276.

† Art. *Vers*, du Dictionnaire des Sciences Naturelles, t. lvii. p. 409.

‡ See his Miscellanea Zoologica, p. 89. "Sectis in dorso longitudinaliter tegumentis, occurrit vasculum lympha sæpe turbidula plenum:" from this sentence it is much more probable that in this section Pallas merely opened the great cavity between the intestine and integument, out of which the "lympha turbidula" escaped, and that it was not the blood-proper, as Milne-Edwards supposes, but the peritoneal fluid which Pallas saw.

§ Annal. des Sciences, 2me série, Oct. 1838, 'Circulation dans les Annelides,' par M. H. M Edwards.

‖ Recherches pour servir à l'histoire de la circulation du sang chez les Annelides, lues à l'Académie des Sciences le 30 Oct. 1837.

¶ 'The Blood-corpuscle considered in its different Phases of Development in the Animal Series,' by T. W. Jones, F.R.S. &c., Phil. Trans. part 2. 1846.

Mr. Wharton Jones describes and figures the blood-corpuscles of the Earth-worm and the Leech, and thus defines the mode in which he obtained the specimens submitted to examination:—

"The blood was most readily obtained for examination from the abdominal vessel, but in abstracting it, care was required to guard against its becoming mixed with the secretion poured out from the skin in great abundance when the animal is wounded," p. 94. Mr. Jones then observes, "The corpuscles of the blood of the Earth-worm are remarkable for their great size, being on an average $\frac{1}{1100}$dth or $\frac{1}{1200}$dth of an inch in diameter. There are both granule and nucleated cells*."

Investigations of the most extended and scrupulously exact description enable the author here to affirm most confidently that in the account of the corpuscular elements of the blood of the Annelida just cited from the memoirs of Milne-Edwards and Wharton Jones, these distinguished observers have fallen into extraordinary errors. *In no single species among the Annelida does the blood-proper contain any morphotic element whatever!* In all instances, without a single known exception, it is a perfectly amorphous fluid, presenting under the highest powers of the best microscope no visible corpuscles or molecules or cells whatever; it is a limpid fluid variously coloured, as originally and correctly described by Milne-Edwards, in different species. No complete distinction into venous and arterial blood can be observed, and the plan of the circulation renders such a distinction only partially possible. In all cases the colouring matter is fluidified and uniformly blended with the fluid mass of the blood; the colour therefore must be *developed* in the fluid mass, for there exist here no morphotic elements in the blood itself by which the separation of the coloured substances from the peritoneal fluid can be effected, unless indeed the parietes of the vessels of the blood-proper discharge this eclectic function. With one exception, namely, that of *Glycera alba*, in which they are red, the corpuscles of the peritoneal fluid are in all species destitute of colour. But it is not at all chemically impossible that the coloured ingredients may exist in this fluid in a colourless state, and that these ingredients, through entering into new combinations, may become brightly coloured after transition into the true blood. In consequence of the impracticable minuteness of the quantity, no direct chemical analysis of the blood in the Annelid can be executed. As to the colour, however, analogy removes all doubt that the red tinge is due to the salts of iron, and the green to those of copper. In those species in which the blood is light-yellow, opake, or lymph-like, it does not follow that the salts of the coloured minerals are altogether absent; they may exist under colourless combinations. The physiologist cannot view with unconcern the question which in this class of animals affects the mode in which the peritoneal fluid and the blood-proper stand related to each other. That the former is higher than the latter in degree of organization no doubt can exist; but it is not quite clear that the true blood is reproduced out of the elements of the peritoneal fluid; since the vessels distributed over the parietes of the alimentary canal may take up some of the immediate products of digestion before the latter exude into the general cavity of the body to mingle with its semi-aqueous contents. Nor can it be affirmed, from the evidence drawn from its composition, that the peritoneal fluid is unfitted to supply the means of nutrition to the solid structures, into the interior of which in every

* Here follows an elaborate account of the metamorphoses which these two varieties of corpuscles undergo; and with respect to the Leech, Mr. Jones states, "that whilst the corpuscles of the blood of the Earth-worm are the largest which I have yet found in any vertebrate animal, the corpuscles of the Leech are the smallest." (p. 95, *op. cit.*)

part of the body it intimately penetrates. It is more probable, because more in accordance with analogy, however, to suppose that it is a manufactory in *itself*, that its corpuscles execute an office by which the mineral substances and proximate principles are vitally assimilated, that the corpuscular elements in the Annelida do in this fluid what in the higher animals analogous bodies effect in the blood-proper. From these facts the physiologist may advisedly say thus much, that in these animals nature divides the vital fluids into two separate and distinct orders, on one of which the preparative and elaborative cell-agency devolves, on the other the work of solid nutrition. They prove with great clearness that the corpuscular elements, either in the blood itself, or as in this case, in some contributory fluid, are *essential* to the preparation of the blood-proper; for when in the zoological series, as in the higher Articulata, this corpusculated fluid disappears, the blood itself becomes corpusculated, or when the peritoneal fluid, as in the Echinodermata, becomes *less organic*, then also morphotic elements are developed in the true blood. From these observations the inference may be further drawn, that between these two nutritious fluids there exists a definite physiological balance, that one is capable of absorbing or merging into the other, according as the observer ascends or descends the organic scale. The peritoneal system of fluid terminates at the standard of the insect, the true blood system traced downwards terminates at the Echinodermata.

Circulating System.—Under this division of our subject we propose to consider only the central apparatus of the true blood-circulation in the *Annelida*, postponing the study of the periphery of this system to the time when, in the order of our arrangement, the branchial, pedal and tentacular appendages shall have to be described.

To Prof. Milne-Edwards is due the merit of having first contributed to science a systematic and exact exposition of the circulating system of the worms. Preceding and contemporary anatomists had indeed offered at different times detached and ill-digested observations on this branch of comparative anatomy. Elaborate memoirs on the organization of some species of Annelida from the pen of M. Quatrefages, have recently appeared in the 'Annales des Sciences Naturelles*.' From the conclusions and descriptions of this naturalist, the author of this Report will have frequent occasion very materially to differ. In the following account, which will be drawn almost entirely from original observations, no order will be observed in the selection of examples. So great is the simplicity of the plan on which the main vascular trunks, constituting the central apparatus of the circulation in Annelids, are arranged, that a few general statements, expressive of leading constructive principles, will be found not inapt as introductory to the study of details:—

1st. In all Annelids the blood flows in the great dorsal trunk from the tail towards the head.

2nd. In all Annelids the blood flows in the great ventral trunk from the head towards the tail.

3rd. In the whole integumentary system of vessels the blood moves from the great ventral towards the great dorsal trunk; this movement constitutes the annular or transverse circulation. The main current of the blood in the ventral trunk pursues a longitudinal course until exhausted by successive lateral deviations.

4th. In the majority of Annelids the intestinal system of vessels consists of four longitudinal trunks: one dorsal, which may be called dorso-intestinal;

* Etudes sur les types inférieurs de l'embranchement des Annelides, par M. de Quatrefages; et Mémoire sur la famille des Hermelliens, 3me série, 1848.

one ventral, which may be distinguished as the sub-intestinal; and two lateral. These several trunks are joined together by circularly disposed branches, bearing a dense, glandular, capillary system. In the inferior intestinal system the general movement of the blood is from before backwards, in the circular branches from the ventral towards the dorsal trunk.

5th. In *Arenicola*, *Nais*, *Lumbricus*, *Hirudo*, the dorso-intestinal trunk sends off the afferent branchial vessels, and these latter return into the great dorsal trunk. In these species the former vessel therefore discharges the functions of a pulmonary artery or branchial heart.

6th. In the *Terebellæ* and *Serpulæ*, which are cephalobranchiate, the anterior extremity of the great dorsal trunk enlarges fusiformly and propels the blood directly into the branchial appendages. In these genera therefore *this* vessel becomes the branchial heart; and the great ventral trunk, into which the efferent branchial vessels empty themselves, becomes the systemic aorta.

7th. In *all cases*, without exception, the three inferior intestinal trunks carry arterial blood, and in nearly all species, the dorso-intestinal venous.

8th. In *Arenicola*, *Nais*, and the *Borlasiæ* and *Liniadæ*, there exists a distinct heart.

9th. In all other species the main *vessels*, more or less modified in different species, constitute the propulsive centres.

To these general statements, which in the Annelida express the main laws of the circulating system, no real exception occurs.

In different species different portions of this system receive augmented development, in accordance, first, with the *method* of the respiratory process, the position of the branchiæ, and the degree of muscular mobility conferred on different parts of the body. In those species in which locomotion is accomplished by alternate and extreme elongation and contraction of the body, the vessels are in all parts remarkably coiled and convoluted. This feature is exemplified most perfectly in *Nais filiformis*. If a part of the body only be endowed with this vermiform mobility, the convoluted character of the blood-vessel is limited to such part; and this embraces most frequently the region of the œsophagus.

In the *Leech* the circulating system is more highly developed than in any other Annelid. The presence or absence of a heart-like centre to this system, is by no means in this class of animals the true criterion of the degree of its evolution. The *amount* of blood relatively to the size of the body, the degree of capillary subdivision which occurs on the periphery of the blood-system, and the proportion of the latter to the peritoneal fluid, form more correct indications. In the Leech there exists no free space between the intestine and integument; to this anatomical fact the highest interest will be subsequently shown to belong when explaining the mechanism of respiration in this Annelid. Here the chylous fluid, which, as formerly shown in nearly all other Annelids, occupies the general cavity of the body, like a cylindrical fluid stratum, separating the intestine from the integument, is transferred into the *interior* of the lateral diverticula of the stomach. The peritoneal chamber being no longer required, is obliterated by the adhesion of the intestine to the integument; the union of these parts is effected through the medium of a dense, spongy layer of capillary blood-vessels, the contents of which are exposed internally to the influence of the fluid contained in the digestive cæca, and externally to that of the circumfluent element; hence the mechanism of the respiratory process, and the power enjoyed by this and other abranchiate Annelids of dispensing with all external breathing appendages. While, however, the peripheral segment of the vascular system in the Leech

exhibits proofs of great complexity, the main currents of the blood obey two leading directions. If the body of the worm be longitudinally bisected by an imaginary, horizontal plane, into a dorsal and ventral semi-cylinder, then the blood in the primary trunks of the dorsal half will move from the tail towards the head, and in the ventral half from the head towards the tail: this movement prevails equally in the great longitudinal trunks of the integuments and alimentary canal. The transverse or circular movement of the blood is performed by means of branches which run between the main longitudinal vessels; this latter system is divisible vertically into as many portions as there are rings in the body of the worm; each segment of the body under this arrangement has its own independent circulation, transverse and longitudinal. Thus the currents describe two eccentric ellipses, cutting each other at right angles; of course the segmental divisions of the general system communicate with each other most intimately at every part, while the primary longitudinal trunks are common to all the segments. From this description it is manifestly impossible that a distinction of venous and arterial blood can exist in the circulating system of this Annelid; in every part of the circumference of each ring the blood is being arterialized as it is being rendered venous; the two opposite processes proceed simultaneously in the same capillary system; the blood must be therefore as arterial and as venous at one and the same time in the dorsal and in the ventral trunks; the dorsal main is notwithstanding recipient, the ventral distributive of the blood; all the secondary currents converge upon the former and emanate from the latter; the blood in both is nevertheless identical in physiological properties.

A diagram accompanying this Report conveys a correct expression of the principles as now explained (fig. 6).

There is, however, in the Leech another distinct and almost independent segment superadded to the general circulation, which, since the æra of the memoirs of M. Dugès*, has been called the respiratory or pulmonary system. If there existed really in nature what this anatomist has described, most wonderful and admirabe indeed, estimated by the Annelidan type, would be this pulmonary system. The illustrations of the singular vessels composing this "minor circulation" for breathing, as originally given in the memoir of M. Dugès, must be familiar to every one who has ever opened a book on zoology; since every European writer, from the year 1828, has servilely copied the figures given by M. Dugès. M. Quatrefages, in the illustrations published in the last edition (Crochard's) of the 'Règne Animal†,' has indicated the *pulmonary hearts* of M. Dugès as the "poches secretrices latérales avec leurs cæcum," an error no less extraordinary than that committed by his eminent predecessor in this branch of comparative anatomy. The following description of the minute anatomy of these parts will prove conclusively, that these two observers, in whose track all modern anatomists, without a single exception, have followed, have imperfectly described what they saw, and saw most incompletely what existed in nature. The curved branches supplying the respiratory sacs‡, to which M. Dugès has assigned the name of

* 'Recherches sur les Annelides Abranches,' Annal. des Sciences Naturelles, t. xv.

† See Plate 24, Vol. sur Annelides.

‡ If the reader will refer to Rymer Jones' 'Animal Kingdom,' Art. *Annelida*, by Milne Edwards, in the Cyclopædia of Anatomy and Physiology, or Owen's 'Lectures on Comparative Anatomy,' he will see that the so-called pulmonary hearts of Dugès, which are represented as thick-walled, fusiform vessels, arising from the dorso-lateral trunk, and breaking into a plexus of capillaries upon the parietes of the so-called respiratory sacs, correspond in outline with the upper edge of the utero-ovarian system as figured in the illustration, fig. 6. More than this resemblance of outline, there is nothing in common between the results of the inquiries and the conclusions of Dugès.

pulmonary hearts, form in reality the edge of the utero-ovarian organ (fig. 6, *f*) The walls of these fusiform hearts are described as muscular, highly irritable, and perforated only by a small bore. The error of this description is so flagrant, that we are constrained to stop, that we may indulge in one more expression of surprise, that English authors for a period of twenty-three years, and that in the epoch of the microscope, should have lent themselves to the propagation of statements so diametrically at variance with nature. The detailed description of these parts will belong to that division of this memoir which treats of the reproductive organs of the Leech ; to this source the reader is accordingly directed for full information.

In addition to the main dorsal and ventral trunks, there exists in this Annelid and in the Earth-worm, two strong and obvious lateral trunks, one on each side (fig. 6, *e*, *e*), as to position and size, correctly enough described by Dugès under the appropriate name of latero-abdominal vessels; the remarkable structure of these vessels has, however, altogether eluded the observation of M. Dugès. In his account they are described as ordinary vessels, while the branches proceeding from them are represented as furnished with very strong muscular parietes. Our researches have led us to conclusions directly the reverse of those of M. Dugès. The *branches* exhibit in their walls a structure precisely the same as that which distinguishes the vascular system in every other part of the body, while the *primary lateral trunks* are provided with remarkable muscular parietes, the fibre of the muscle being of the striped kind. The fascicle of the muscle composing the walls is arranged in a manner which is quite distinctive of and peculiar to this vessel (see fig. 6, *e*, *e*); it is coiled with so much regularity as to enclose a perfect cylinder, in which the blood flows; the longitudinal fibres are almost entirely suppressed; the circular fascicles, lined within by a hyaline membrane, constitute therefore the exclusive coat of the vessel; such a vessel is almost unique in structure in the animal series, but none other would perform so admirably the peculiar duties for which it is introduced into this part, obviously as a special provision. Its business is to transmit with augmented force a current of blood, in a transverse direction, from the side to the utero-ovarian organs; these organs form a double longitudinal series, one on either side of the ventral mesial line* in each annular segment of the body. An express branch from the latero-abdominal trunk on either side is rendered to these reproductive organs (fig. 6, *h*); so that the amount of blood propelled by this vessel, measured in its totality, must be very considerable; and the quantity, during the generative season, must undergo great increase, in consequence of the augmentation of size which at this period these organs experience. The lateral longitudinal vessel is strikingly adapted to meet such alternations of extremes; constructed of muscle, it readily yields under the *flow* of the blood-tide to the organs to whose wants it ministers; and constructed of muscle, its parietes augment by accelerated nutrition during the periods of increased local determination of blood; formed of any other structure than muscle, such admirable adaptive alternations could not happen.

In the dissections of Quatrefages†, the great dorsal trunk in the Leech is correctly represented as common to the integument and intestine. In consequence of the layer of pigmental glandular cells by which all the vessels in this Annelid are enveloped, to trace their courses individually is rendered, practically, very difficult.

The *Earth-worm* exhibits a vascular system (Plate III. fig. 7), of which the plan coincides in a remarkably intimate manner with that of the Leech. This correspondence between the circulatory systems of these two Annelids arises

* Vide Reproductive Organs, &c.

† Règne Animal, Vol. *Annelides.*

from a similarity in the structure and disposition of the utero-ovarian organs; while the male organs in these two worms strikingly differ in structure and arrangement, the female systems are almost identical. To this system in the Earth-worm, again, M. Quatrefages has erroneously applied the description of "*Secretory pouches*," "poches secretrices venant s'ouvrir sur le dos par les canaux renflis*." The primary longitudinal trunks are similar in number and disposition to those of the Leech; the direction of the blood-current is also the same. In the dorsal longitudinal half of the system, the blood moves from the tail towards the head; in the ventral, contrariwise. In the Earth-worm, in this respect distinguished from the Leech, the intestine is only tied to the integuments at the interannular points; the intervals or segmental spaces being left as chambers, containing a small quantity of viscid corpusculated fluid, which is the peritoneal fluid of this worm. The interposition of a fluid stratum in this part involves other anatomical modifications, which still further separate the organization of the Earth-worm from that of the Leech; the spongy vessels described as occupying this part in the latter are absent in the former. The intestine as well as the integuments are reticulated with elaborate capillary plexuses (fig. 7, *f*), both of which enact a part in the process of respiration. The complex character of the peripheral circulation in the Earth-worm, proves with great force the inverse proportion which in all Annelids exist between the volume of the blood-proper and that of the peritoneal fluid. In this worm accordingly, from the denseness of the peripheral capillaries, the physiologist may predicate almost the absence of the peritoneal fluid.

Superadded to the primary median blood-channels (fig. 7, *a* and *d*, *c*), a minor lateral system, founded upon the latero-abdominal trunk, may be demonstrated in the Earth-worm as in the Leech; in all essential particulars in the two cases, the main trunk of the system and its branches are the same. The Earth-worm is essentially a water-breathing animal; it dies in pure water from starvation, in dry air from asphyxia; the character of the circulatory fluids obviously suggest the above inferences. The larger blood vessels, wherever they come into relation with the intestine, are more or less embraced by the peritoneal membrane of this canal, and in this, as in all worms, this membrane is intimately adherent to the biliary gland-cells. In its foldings, this structure, with its yellow-coloured cells, more or less envelopes the vessels, and gives to them the appearance of being surrounded by a spongy pigmental coat. M. Merren, in the refinement of his dissections, saw in this covering a separate structure, and distinguished it as the "*Chloragogena*!" An order of vessels in the circulating system of the Earth-worm now presents itself, to which there exists no parallel in that of the Leech. At the segments occupied by the testicular masses, the great dorsal trunk detaches symmetrical, lateral, successive branches (fig. 7, *b*, *b*) of large calibre, to the number of seven or eight, which vertically embrace the œsophageal intestine, and empty themselves, without subdivision, into the ventral trunk. By Dugès and *all* subsequent writers these vessels have been called the *moniliform* hearts. Quatrefages, in his recent and beautiful illustrations, published in Crochard's edition of the 'Règne Animal,' has depicted these vessels as consisting of a succession of beads, as moniliform as those given in the lectures of Sir Everard Home, or by the ancient Willis, in his classic work 'De Animâ Brutorum!' In real truth, these vessels are not in the slightest degree whatever *moniliform*; they consist of nearly uniformly outlined cylinders; the middle of each vessel, however, is slightly bulged (fig. 7, b'''). They constitute direct com-

* Crochard's edition of the Règne Animal, Vol. *Annelides*, pl. 21. Extrait des recherches inédites sur les Annelides, par M. de Quatrefages.

munications between the dorsal and ventral trunks; in them the blood sets vertically downwards from the dorsal to the abdominal vessels. In other vertical vessels situated more posteriorly and parallel to the so-called moniliform hearts, the blood moves in a converse direction from below upwards: the moniliform character which these vessels exhibit is produced by the process of dissection. If, in the ordinary way, a longitudinal dorsal incision is made, and the two halves be then separated and pinned down, the vessels under such tension are sure to assume a moniliform outline; that is, one part will contract, and another will dilate, and so on successively throughout the length of the vessels; the dilated portion will be filled with blood, and the contracted will be empty, and the beaded figure will be perfect. If, however, a more careful mode of opening the worm be adopted, dividing by means of a fine scissors the membranous segmental partitions, and laying gently open the integuments, these vessels will present a perfectly smooth outline; if now one of them be seized with the forceps and gently pulled, it will become irregularly knotted or moniliform. Muscular fibres, chiefly circular, are present in their parietes, and it is to the uneven action of these elements that the beaded form is attributable. The contraction of the circular fibres at two points separated by a short interval, imprisoning in that interval a globule of blood, the same conditions occurring at another part, explain clearly the mode in which the moniliform character occurs. Every European writer for the last thirty years has glowed with admiration in describing these "moniliform hearts" in the Earth-worm! And yet even without the refutations of demonstrative anatomy, how easy, on a little mechanical consideration, would it have been to see that *no form* of vessel could have been mechanically *less* adapted for reinforcing the moving power of the blood-current than a conduit composed of a succession of contractions and dilatations! it is evident that the efficient propeller would be the last dilatation only in the series. A spindle-shaped tube, on the other hand, and muscularly contractile, will be seen to realize all the physical conditions required under such circumstances for imparting a new impulse to the moving current. The latero-abdominal trunks, destined for the supply of the utero-ovarian system, are present in the Earth-worm, and present a structure and relations analogous to the corresponding vessels in the Leech; in the latter, however, the circular muscular fibres are much more developed than in the former, and the vessel is relatively larger.

It was imagined by Willis* that he had discovered the existence of a series of pores upon the dorsal aspect of the Earth-worm, which by him were construed into stigmata; and in confirmation of their perforate character, he relates that air blown into the openings is dispersed between the integument and intestine, diffusing itself throughout the segmental compartments. It is stated by Dugès that he has repeated these experiments with the same results, finding that the pores, instead of terminating in muciparous follicles, as they were supposed to do by many anatomists, penetrate into the interior of the body, so that air injected into one of them passes freely along the segmental chambers which surround the intestine and escape through other neighbouring orifices. By these distinguished authors it is further affirmed, that water is imbibed into the segmental chambers through the same orifices, and from which it is given out when the animal is too rapidly dried by exposure to the sun, or irritated by external stimuli. And it is conjectured that aërated water thus taken into the system, and brought immediately into contact with the deep-seated vascular network dispersed over the intestinal parietes, must, therefore, necessarily contribute to the respiratory formation.

* De Animâ Brutorum, 4to, 1672.

These observations of Willis and Dugès are totally irreconcileable with the facts adduced in this Report:—first, the alleged orifices (stigmata), communicating directly with the cavity of the body, cannot now be proved to exist; and secondly, it is susceptible of demonstration that the fluid contained in the peritoneal space is not *watery* in this worm, even though it may have been immersed for some hours in water previously to the examination. As already described, the contents of the cavity are composed of a viscid, corpusculated fluid, insusceptible, from its consistency, of such rapid removal as is implied in the above observations. The orifices which communicate with the interior in this worm, as in nearly all others, open directly into the membranous utriculi of the generative system. No other perforations can be proved to exist.

In *Nais filiformis*, so abundant in the freshwater pools of this country, the anatomist is presented with a favourable opportunity for resolving the problem of the circulation (fig. 8). A living specimen, placed between two slips of glass, from the perfect transparency of the integuments, will exhibit to the eye, in a perfect manner, all the circulating movements both of the vessels and the blood. In *Nais*, the large dorsal vessel (fig. 8, a) is first seen travelling wavingly along the dorsum of the intestine as far as the heart, which corresponds in situation with the intestinal end of the œsophagus. This vessel is enveloped by the glandular peritoneal layer of the intestine, while the coats of the ventral vessel are clear and transparent; the dorsal vessel is endowed with parietes of greater strength and density than the ventral. Each of these vessels (as at fig. 8, a', b') dilates into a fusiform heart, which is situated on either side of the œsophagus. These hearts, which are joined together by transverse vessels, pulsate *alternately*, and with exact regularity. In the dorsal vessel the blood moves forwards *from* the tail, as far as the dorsal heart; thence it descends into the ventral heart, by which it is now propelled, chiefly in a *backward* direction, partly through the main ventral trunk, and partly through the inferior intestinal. The other portion of the blood, conveyed by the great dorsal vessel into the ventral heart (b'), passes forwards as far as the head, where its moving power is again reinforced by a cardiac dilatation, which now impels the current from before backwards through a superior œsophageal trunk into the *dorsal heart* (a'), by which organ, the blood, received from the region of the œsophagus, and coming from the head, as well as that received from the great dorsal, and coming from the tail, is urged downwards into the ventral heart, and thence, chiefly in the direction of the tail, through the ventral and intestinal trunks (e, f); this latter, therefore, is the true systemic heart. At the œsophageal end of the body the two primary trunks, dorsal and ventral, are connected together by means of a remarkable class of vessels (g, g, like g, g', g), which in this region proceed at successive points from the dorsal œsophageal, and which may be traced in long coils, *without division of the vessel*, floating in the fluid of the peritoneal cavity. Posteriorly to the heart-centre these vessels (fig. 8, g, g, g) emanate from the dorsal *intestinal* (b), and correspond precisely with those branches from the same vessel, which in *Arenicola Piscatorum* proceed to supply the branchial arbuscles. In *Nais*, therefore, partly from this analogy, but chiefly from their anatomical relations, bathed by, and floating in, the chyl-aqueous contents of the peritoneal cavity, the physiologist can experience no difficulty in dedicating these coiled vessels to uses very definite. First, it cannot be doubted that they absorb from this fluid the elements by which the blood-proper is formed and replenished; and secondly, it is in the strongest degree probable, that the true blood is in *great part* aërated through the agency of these vessels upon the gaseous elements contained in the peri-

toneal fluid. They constitute the *special* branchial system of vessels (internal branchiæ), while they discharge incidentally an absorbent function. In the movement of the blood, then, in *Nais* as in *Lumbricus*, there are discernible only two leading directions,—one forward, in the primary and intestinal dorsal vessels (fig. 8, *a*, *b*), the other backward, in the primary and intestinal ventral (fig. 8, *d*, *e*, *f*). It is not possible to trace the blood into the capillary parietal system of the intestine, in consequence of the transparency of the stream when thus minutely subdivided. In *Nais* there is also an integumentary system which intervenes between the two primary (dorsal and abdominal) trunks (*a*, *f*), ramifying on the substance of the integuments, upon which in part a respiratory function may devolve.

In the *Terebellæ*, in consequence of the concentration of the tentacles and branchiæ around the head, the blood-system at this extremity of the body discovers a great increase of development. The peritoneal fluid in this genus is very voluminous and densely corpusculated; the system of the blood-proper is notwithstanding elaborate and full-formed. The chamber of the peritoneum is one undivided space—the segmental partitions of the Earth-worm and the Leech being here replaced by limited bands proceeding from the intestine to the integument, tying together these two cylinders, such as to permit one to move longitudinally within the other with remarkable freedom.

The great dorsal vessel in *Terebella nebulosa* is limited to the anterior extremity of the body (fig. 9, *a*). It emanates chiefly from a large circular vessel (*b*), embracing the base of the œsophagus which receives the whole blood of the intestinal system. In this species, therefore, the primary and intestinal dorsal trunks, over the whole intestinal region, are united, or the former vessel is superseded by the latter.

On the dorsal view of the œsophagus, a large, pulsatile, fusiform vessel (*a*) is displayed on the first opening of the integument in a longitudinal direction. Little attached to the structure on which it rests, it appears as if suspended in the fluid of the peritoneal cavity. Advancing to the occipital ring, it breaks out into six branches (*d*), of which three proceed to the branchiæ of each side, while the reduced continuation of the original trunk furnishes minute ramuscules to the tentacles, in the hollow axis of each of which an afferent and efferent vessel is contained, surrounded by the peritoneal fluid, which penetrates to the remotest ends of these exquisite organs. Both from the tentacles and branchiæ, the blood now returns into the great ventral trunk (*c*), which to the posterior extremity of the body is distinct from and independent of the intestinal system (*f*). From this trunk branches are detached on either side of the median line, for the supply of the feet and integument.

At the point corresponding with the circular vessel (fig. 9, *b*), the primary ventral sends off a considerable division for the supply of the intestinal system. The current therefore entering the glandular parietes of the intestine is purely arterial in this genus, for it is unmixedly composed of blood returning from the tentacles and the branchiæ, by both which the function of respiration is performed. Here again there exist but two principal directions in which the blood circulates, viz. longitudinally and transversely, or circularly, the former currents being connected by the latter. The circular vessel (fig. 8, *b*) acts like an auricle; it receives the blood from the intestinal system and delivers it into the great dorsal (*a*). The alimentary canal is embraced in this genus, as in all Annelids, by a framework of longitudinal and transverse vessels, in which the blood moves backwards below and forwards above (*f*).

In *Terebella conchilega* the circulating system is planned on the same type with that of the former species. Here, as in the former case, the main

agent of the circulation is seen in the large œsophageal dorsal trunk, which commences at the confluence of the intestinal longitudinal vessels. The ventral-most of these latter, on rising to the dorsal aspect of the canal and meeting in the common dorsal œsophageal, produce, as in *T. nebulosa*, the appearance of the vascular ring encircling the œsophagus. The infra-neural or ventral trunk, bearing a current from the branchiæ and tentacles to the intestine and integument, constitutes the apparatus for the systemic distribution of the blood, the dorsal œsophageal being the true branchial heart. The alimentary canal, posteriorly to the ring-vessel, is embraced in a framework of four longitudinal trunks, severally communicating through the medium of glandular capillary plexuses. The peritoneal fluid in this species is less voluminous than in the former. The peritoneal space is a continuous chamber, and the parietes are vascular. The tentacles, organized nearly as in the former species, are smaller and fewer in number.

The resemblance is remarkable between the circulating system of the *Euniciadæ* and *Terebellæ*. At an early period M. Delle Chiaje recognised and described the leading features of the blood-system of *Eunice gigantea*, under the name of *Diopatre**. M. de Blainville has also given some account of the circulation of this worm†. To Milne-Edwards belongs the honour of having first fully and minutely investigated the anatomy of the circulatory system in this and other Annelida. In accuracy his description is not to be surpassed. It is only in one particular that the author's account, which has been drawn with repeated care from his own dissections, will be found to differ from the statement of Milne-Edwards‡.

As a great degree of mobility is conferred upon the cephalic extremity of the body in *Eunice*, and as the protrusile œsophagus is considerably less vascular than the intestine, the great dorsal vessel occurs here as in the *Terebellæ* under the character of an *un*branching tube, reaching from the in-

* Memoire sulla storia e uotomia degli Animali senza vertebre del regno di Napoli, t. ii. p. 396.

† Art. *Vers* du Dictionnaire des Sciences Naturelles, t. lviii. p. 405.

‡ Compare the diagram given by the French naturalist, of the circulating system of *Eunice* (pl. 12, fig. 2, Annales des Sciences Naturelles, sér. 2, Octobre 1831) with the author's description as given in the text with reference to this Annelid, a worm which probably attains less gigantic proportions in this country than on the southern parts of the coast of France, and the reader will perceive that the lateral branches going, at each segment, into the branchiæ, undergo *no heart*-like dilatation as represented in the illustration of Milne-Edwards. In relation to these branches the description of this profound anatomist runs as follows:—" Enfin par son extrémité antérieure, le vaisseau dorsal envoie divers branches à la tête et d'autres rameaux qui se portent en dehors comme chez les Térébelles, mais qui, au lieu de se rendre aux branchies, remontent en arrière et vont se distribuer au pharynx où leurs divisions s'anastomosent avec celle du vaisseau ventral. Ce dernier tronc suit le même trajet que chez les Térébelles et donne également naissance, dans chaque anneau du corps, à une paire de branches latérales. Mais la conformation de ces branches est différente ainsi que leur usages. Aussitôt après sa naissance, chacune d'elles se renfle beaucoup et se recourbe brusquement sur elle-même, de façon à ressembler, lorsqu'on l'examine superficiellement, à une vésicule ovulaire, disposition qui a probablement induit en erreur M. Delle Chiaje, quand il a annoncé l'existence d'ampoules ou pouches arrondies, situées sur le trajet des branches latérales du vaisseau dorsal de l'Eunice gigantesque. Ces vaisseaus transversaux se portent ensuite en dehors, fournissent une branche ascendante au tube digestif, gagnent la base des pieds, y donne naissance à plusieurs petites branches anastomiques dont la réunion constitue un lacis vasculaire, et a des ramuscules destinés aux muscles et aux tégumens voisins; enfin pénètrent dans les filamens branchiaux correspondans et s'y terminent. Le sang qui a subi l'influence de l'oxygene, à travers la surface de ces appendices dermoïdes, est reçu dans d'autres canaux transversaux qui se dirigent vers le tube digestif en suivant les cloisons interannulaires, et débouchent dans le vaisseau situé de chaque côté de la ligne médiane sur la face dorsale de cet organe." In the references to the diagram Milne-Edwards describes these lateral branches which supply the *branchiæ*, as "bulbes contractiles de ces branches 'latérales' remplissant les fonctions de cœurs pulmonaires."—*Op. cit.*

testinal commencement of the œsophagus to the occiput, and, tortuous and little attached, reposing on the upper surface or œsophageal portion of the digestive tube. Coinciding with the whole extent of the intestine-proper in this worm, the anatomist will observe a *double* vessel along the dorsal-median line, and lodged in parallel apposition in the longitudinal sulcus of the upper surface of the alimentary tube. These two trunks belong to the intestinal system, receiving branches however at numerous points from the integumentary veins. In these vessels the blood moves from behind forwards, and mingles in the œsophageal circular vessel with that coming from the lateral intestinal, in which also the blood-stream sets anteriorly, while in the inferior intestinal, as in the great sub-ganglionic or ventral, the current sets in the direction of the tail. In this Annelid the branchiæ are limited to the posterior two-thirds of the body, each branchia consisting of two, three, four or five blood-vessels, according to the species, projecting in a comb-like manner from the dorsal base of each foot. The great heart-like œsophageal dorsal vessel therefore, while anatomically similar, is physiologically very different in this worm and the *Terebellæ*. In the latter species it is exclusively a branchial heart, in the former it is indirectly systemic and branchial. It empties itself into the anterior extremity of the main ventral trunk, by which the lateral segmental branches are directly supplied to the feet, integument and *branchiæ*.

It was formerly stated that Milne-Edwards has described and figured the branchial vessels as ampullated soon after the origin of each from the common trunk, the ampullæ being designed to fulfil the function of branchial hearts. These vessels, therefore, according to the representations of Milne-Edwards, are, in *Eunice*, the exact analogons of those remarkable cardiac vessels (pulmonary hearts) described by M. Dugès in the Leech. The existence of these latter vessels has already been demonstrated, beyond doubt, to be altogether imaginary, M. Dugès having mistaken for them the curved edges of the reproductive utriculi. According to the author's observations, these vessels in *Eunice* present nothing approaching to the ampullæ figured in the illustrations of Milne-Edwards. The pouched dilatations are *produced* by the dissection and exposure to atmospheric stimulus, just as in the Earthworm the moniliform character of the descending vessel was shown to be caused by the *stretching*. In *Eunice* the lateral segmental branches are relatively large at first, but soon divide into three lesser branches, of which one goes to the feet, the other to the intestine, and the third to the branchiæ, from which the blood returns into the dorsal vessel, which in this worm accordingly carries arterial blood. The suddenness of this division favours the imprisonment of a drop of blood in the first stage of the vessels, the drop thus enclosed occasioning a bulged enlargement in this portion of the vessel; but that this appearance is altogether accidental, the author has repeatedly, and with various kinds of proof, shown to be unquestionable. The blood is admitted into and returned from the branchiæ by alternate movements of contraction and dilatation; these movements are not simultaneous in all the branchiæ, but variously and independently in each individually, the afflux into one being synchronous with the efflux of blood from those contiguous. This contractile power is by no means peculiar to these vessels. The motion of the blood in the vessels in every part of the body of the Annelid is effected, not through the agency of uniformly travelling undulatory contractions of their coats, but by complete contractions and relaxations of successive portions of the tube; so that during the instant of contraction, the cylinder of the vessel in the part contracting is completely emptied of blood, the sides collapsing and meeting in the axis; and during the period of dilatation, the

same portion of the vessel becomes densely distended with blood; and this is the true mechanism of the circulation in those species even in which a central propulsive organ exists, for example, in *Nais* and *Arenicola*. In no part of the system, therefore, is the superadded contractile bulb required as an agent of circulation, since this contractile power resides in every part of *every* vessel, in virtue of the muscularity of its parietes. The truth of these observations, opposed as they are to the statements of Milne-Edwards, may be established beyond doubt, and easily, by a scrutiny of the circulating system of *Arenicola Piscatorum**.

A general survey of the circulation in *Eunice* will suffice to satisfy the physiologist that no part of the system contains pure arterial and no part pure venous blood. Into the double dorsal trunk arterial blood is poured from the branchiæ, but into the same trunk the intestinal branches contribute venous blood; the mingling of these two classes of currents in the same trunk must result in blood of an intermediate quality. It is then manifest that the great subneural trunk, which in this worm is both systemic and branchial, must distribute blood of composition intermediate between venous and arterial. No part of the circulatory apparatus therefore contains pure arterial blood but the efferent branches of the branchiæ.

The *Sabellæ*, in the number and general disposition of the primary blood-vessels, do not very materially differ from those Annelids of which the circulatory apparatus has been already described. The evidence of "centralization" is less complete in this genus than in the genera *Eunice* and *Terebella*. The dorsal vessels preserve a uniform diameter from origin to termination. In *Sabella alveolata*, the dorsal vessels, which repose on, and belong to, the alimentary tube, commence at the caudal extreme of the body as a small single trunk. Where the true intestine begins, as indicated by the segmental sacculations of the canal, this single vessel divides into two trunks perceptible on the dorsum of the intestine, which on either side of the median line proceed forwards in parallel directions. At the crop-like dilatation, which occurs at the commencement of the œsophagus, these two vessels are united by a large transverse branch, and advancing round the sides of the crop-like bulge, become again united into a single trunk, which follows the œsophagus as far as the occiput, where it resolves itself into numerous minute branches for the supply of the cephalic tentacles. These latter organs are penetrated by the peritoneal fluid which moves to and fro in a hollow axis, along which a single delicate blood-vessel reaches the extreme end of the tentacle and then returns upon itself. The functions of these tentacular ramusculi have reference more to an absorbent than a respiratory process. In this worm the sub-ganglionic trunk is comparatively small, while the sub-intestinal is more developed. It is from the latter and not the former vessel in *Sabella alveo-*

* Speaking of the circulating system in *Eunice*, this anatomist thus expounds the mechanism of the circulation :—" Les vaisseaux sanguins, considérés d'une manière absolue, se distribuent donc à-peu-pres de la même manière chez les Eunices et les Térébelles, mais, si on les considère dans leur fonctions et dans leur rapports avec l'appareil respiratoire, on y voit, dans ces deux genres, des différences très grandes. Dans les Eunices, le cours du sang n'est pas déterminé par les contractions des branchies ni même du vaisseau dorsal, dont l'action perd presque toute son importance; mais par les battemens de bulbes contractiles formés par la dilatation de la base de chacune des branches transversales du vaisseau ventral. Ces bulbes au nombre de deux dans chacun des anneaux du corps, excepté les six ou sept prémiers, envoient le sang aux branchies en même temps qu'à l'intestin, aux muscles, à la peau, etc., et par conséquent, sous le rapport physiologique, ils représentent autant de cœurs. On en compte quelquefois plusieurs centaines; et cette multiplicité des organs moteurs du sang, indépendans les uns des autres, est probablement une des circonstances qui donnent aux tronçons du corps de ces Annelides la faculté de vivre pendant fort long-temps après avoir été separés du reste de l'animal."

lata that the lateral branches designed for the branchiæ proceed, the efferent vessels of these organs returning the arterialized blood into the dorsal intestinal trunks. Between the longitudinal trunks a complex capillary system of vessels is interposed. Upon this system the glandular functions of the biliary cell-layer of the alimentary canal depend. From the relative connection and directions of the primary and secondary trunks, it may be seen that the blood in all the lateral branches connected with the *dorsal* vessels sets *towards* the median line, while that in the *ventral* secondaries sets *from* the median line. In this Annelid therefore, as in *every* other, there are two concentric *circular* currents, while in *many* there exist also concentric longitudinal movements of the blood.

On the British shores two other species of *Sabellæ* are familiar, of which the circulating system is distinguished in several respects from that of *Sabella alveolata*. In *S. à sang vert* of Milne-Edwards* the dorsal vessel is single, maintaining a median position from one extreme of the body to the other. It is branchial in office. Situated at the cephalic end of the body, the entire blood of the branchial tentacles is derived immediately from this vessel. Its contributory branches proceed from the intestine and integuments; its contained blood is necessarily venous. The sub-neural trunk receives the branchial veins. This vessel in *Sabella chloræma* is large, and distributes unmixed arterial blood to the feet, integuments and intestine. There exists in this worm a considerable amount of peritoneal fluid, which, in common with the blood-proper, penetrates into and follows the subdivisions of the branchial appendages. The blood, bright-green in colour, is perfectly destitute of all morphotic elements; it is entirely fluid. The peritoneal fluid is colourless and corpusculated. The blood-current in this Annelid observes two leading directions: in the dorsal vessel it moves forwards, in the ventral backwards, in the lateral branches upwards and circularly, in conformity with the law controlling the circulation in all Annelida.

In the subsequent portion of this Report another species of *Sabella* will be described, in which the *branchial* tentacles coexist with the bilateral series of branchiæ. In this graceful Annelid the features of the circulating system of *S. alveolata* and *S. chloræma* are interfused. The species characterized by Montagu as *Sabella vesiculosa*, in which the branchial appendages are concentrated around the head, exhibits a blood-system, of which the dorsal vessel is single and branchial, conforming in every detail with that of *S. chloræma*.

The *Nereidæ* are elaborately organized; the blood-system is highly developed; the peripheral portion is densely subdivided; the nervous system is numerously ganglionized. Thus is explained the vigorous muscular power of nearly all the species of this genus.

In *Nereis margaritacea* of our coasts the system of the blood is double. There exists a primary dorsal vessel and intestinal dorsal, much smaller than the former. This latter vessel is *not* represented in the diagrams of Prof. Milne-Edwards, but it may be readily exposed to view. The superior or greater dorsal presents its largest diameter about the middle of the body. It receives at every segment considerable venous branches from the intestine, and arterial from the bases of the feet. Anteriorly about the commencement of the œsophagus it sends down to the great ventral a large proportion of its blood by means of descending lateral branches, like the moniliform (*sic*) vessels of the Earth-worm.

* I have constructed a Greek specific name for this elegant Annelid, namely, *Sabella chloræma*, in accordance with the French designation applied to it by Milne-Edwards, both signifying the existence of *green* blood.

The sub-ganglionic trunk in this worm exceeds the dorsal in calibre; it re-circulates throughout the system the contents of the dorsal trunk; lateral branches, slightly coiled and lengthened, a provision against injury during the vermiculations of the body, are detached at each ring, to the feet and intestine. Those for the former penetrate at the roots of these appendages and reach the cutaneous surface, whereon a complex network of capillary vessels is formed, veiled from the exterior only by a layer of epithelium. This plexus is the true respiratory organ of the *Nereid* (see fig. 13, *a*). This plexiform subdivision of the vessels is not seen in many worms; it is a formation almost peculiar to the *Nereids*. In the neighbourhood of these respiratory plexuses, artfully arranged, a system of vibratile cilia is provided, without which the great function devolving on these vessels were incompletely discharged. The intestine is embraced in a framework of four longitudinal vessels, between which a glandular capillary system intervenes, which provides the digestive secretions.

In the *Nereids*, then, no heart-like centre to the circulation exists. The great dorsal, the reservoir of the centripetal streams of the body, may be likened to a right ventricle (the lungs cut off), and the great ventral to a left ventricle. The duty of the former is to collect the refluent blood of the system, of the latter to circulate it again.

A slight modification in this system occurs in *Nephthys Hombergii*, a dorsibranchiate Annelid allied to the *Nereids*, and common on our coasts. A strong proboscis, enclosed in an œsophagus of corresponding strength, by its constant motions would, in this worm and in this situation, endanger the safety of lateral vessels. The position of these branches is accordingly thrown back as far as the commencement of the intestinal division of the alimentary tube. The crowding of the branchial veins upon this point of the vessel imparts to the latter an augmented diameter or a heart-like form. The vessel then creeps along the dorsal surface of the proboscidian œsophagus, neither giving nor receiving branches, as far as the occipital segment, where it divides into two branches which descend on either side to the ventral trunk, while a few small twigs proceed forward to supply the tentacles. In this worm a distinct branchial organ is provided, which is situated at the inferior base of the superior foot. The branchial veins stretch across the peritoneal space and empty themselves directly into the great dorsal vessel. As in the *Nereids*, the afferent blood-vessels of the branchiæ are derived from the great ventral; the branches corresponding in number with the segmental divisions of the body. It remains to note a peculiarity of the ventral or sub-ganglionic system in *Nephthys*, which Milne-Edwards was the first to recognise. The vessel, which is a *single* trunk in all other Annelids, is *double* in this. The parallel trunks, however, communicate freely here and there by cross branches. It appears then that the lateral series of vessels of one side destined for the branchiæ are independent of those of the other. This conformation, so remarkable, has a meaning. It is a beautiful provision against the consequences of injury, to which the habits of this worm render it obnoxious.

The resemblance is most striking between the circulating system of *Nais filiformis* and that of *Arenicola Piscatorum* (fig. 10). From the dimensions of this last worm, it is easily dissected; the older anatomists had discovered the existence of a heart-like centre. Hunter, Sir E. Home and Lamarck, have each described the blood-system of this vulgar worm. But it was reserved to Prof. M. Edwards to unravel its details with a demonstrative accuracy worthy of modern science. Nothing remains to be added to the account given by this naturalist. The blood-system is more centralized in this worm than in

any other known Annelid. A large dorsal trunk (a) at the anterior three-fourths of the body, receiving exclusively the efferent vessels of the branchiæ, proceeds forwards from the tail and empties itself into the cardiac cavities, of which one is situated on either side of the œsophagus (b, b). Another vessel, proceeding *from* the head towards the heart, empties itself into the same cavity with the former. The blood then enters a second cavity (c', c') more ventrally situated, by which it is propelled forwards into the subœsophageal trunk, but principally backwards into the great longitudinal trunks of the alimentary canal. The blood, returning from the intestinal system of vessels, reaches the dorsal intestinal (g) (lying in the median line, underneath the great dorsal trunk), from which the current diverges laterally at right angles into the branchiæ (f, f). This conformation differs from that prevalent in all other dorsibranchiate Annelids, in which the great ventral trunk is the source of the branchial *arteries*. But the typical plan of the circulation is observed in the system of *Arenicola*, at the posterior half of the branchial division of the body, whereas the afferent vessels of branchiæ emanate from the ventral trunk. It may be necessary to explain that the motion of the blood in that part of the circulating system which is anterior to the heart is the reverse of that in that posterior to this centre. The ventral œsophageal carries the blood forwards and the dorsal backwards towards the heart.

The independent contractile (*ergo* circulating) power of each individual vessel may be very completely proved by an examination of the branchiæ of a living *Arenicola* (see fig. 12). A single ramuscule in the branchial tuft may contract and empty itself, while the surrounding branches are expanding diastolically. There is no synchroneity in the circulatory movements of these vessels. Both the afferent and efferent vessels of the branchiæ are long and tortuous, but discover *no cardiac ampullæ* in any part of their course. In fact such formations exist in no known Annelid, and this conclusion has now been substantiated by anatomical demonstration.

Over the parietes of the stomach in this worm a very dense reticulation of capillary vessels may be observed with the naked eye, from the bright yellow colour of the biliary gland-layer. In *Arenicola* the peritoneal chamber is filled with a highly corpusculated fluid, the basis of which consists of sea-water, and the presence and movements of which are indispensable to the circulation of the blood-proper. By this remarkable mass of fluid, the slender, tortuous vessels are shielded from injurious pressure.

In the *Borlasiæ*, a genus of Annelids, of which the true organization is explained for the first time in this Report, the central organ of the circulation occurs as a bilocular heart, which is situated on the dorsal surface of the proboscis and near the occiput.

This organ, in every species of *Borlasia* hitherto examined by the author, consists of two chambers, between which, by means of a large transverse channel, a free communication exists; into one of these cavities the blood of the dorsal vessel is poured. This blood is derived from the cutaneous system of capillaries, which in these worms are superficially situated, and only protected from the surrounding element by a coating of vibratile epidermis. This vibratile epidermis is limited to the dorsal half of the body, which may be therefore assigned as the true area of the respiratory process. Vibratile epidermis in all other Annelids is restricted to special localities, wherein the function of respiration is performed. In the *Borlasiæ* and *Liniadæ* it is co-extensive with the whole dorsal region of the body, and becomes a distinctive anatomical character of these unfamiliar genera. From the dorsal chamber of the heart, the blood through the connecting channel is directed into the ventral cavity, and thence distributed over the integumentary and intes-

tinal systems. The extreme elongation of the body in these worms necessitates the existence of a central propulsive power, notwithstanding the contractile property with which every part of the circulating system is endowed. In these singular worms, the alimentary system of which will be afterwards described, the blood-proper is red in colour, and perfectly devoid of globules of any sort. The peritoneal space, as it exists in most other Annelids, is not to be found in these genera, since the alimentary organ superadded to the proboscis and œsophagus is adherent to the general integument.

A general idea has now been given of the central agents of the circulation of this class of invertebrate animals. The special elaboration of the circumferences of this apparatus to meet the exigences of local and special functions, will be further considered in describing the ultimate structure of the several gland-organs of the body. Over the intestine the blood-vessels ramify in accordance with a special *plan* of subdivision. This observation applies also to all the other constructional elements of the organism: each is provided with its peculiar order of blood-vessels. A subordinate system of blood-vessels, distinct and remarkable in its anatomical relations, is susceptible of demonstration in all Annelids in which the peritoneal fluid exists. These vessels may generally be distinguished by their *coiled length*, perfect nakedness, and floating in the fluid of the cavity, and *un*branching (see again fig. 8, *g*, *g*, *g*). And, finally, it must impress the physiologist with surprise, that amid so great apparent complexity of arrangement in the blood-vessels of the Annelida, it should be possible to reduce the movement of the blood to a single definite orbit of remarkable simplicity. The anatomical details now presented suffice to establish the general propositions formerly enounced, which indicated only two circles of motion, longitudinal in the primary trunks, circular in the secondary.

Integumentary System.—The integumentary system will anatomically include a consideration of the whole apparatus of the appendages, wherever these latter are found to exist. In the organization of the Annelida, no part presents such constancy and fixity of character as the *hard* elements of the appendages. They constitute the least fallacious ground for the classification of species. The *soft* elements, on the contrary, are liable to endless variations from age and the accidents of growth. The appendages in all cases are true productions of the integumentary structures. In no instance do they exhibit any connexion whatever with the visceral and intestinal systems. All Annelida are comprised in the twofold division of *Branchiata* and *Abranchiata*; this however is neither an unobjectionable nor a convenient distribution. Several species exist, of which the soft pedal appendages do not contain a specially organized branchial element: this remark is true of all the *Syllidæ*. The proposition is notwithstanding not difficult of anatomical proof, that the Annelida are really divisible into those which *have* and into those which *have not* external and apparent branchial organs. M. Dumeril had realized a clear conception of the practicableness of such a division, when he proposed the terms *Cryptobranchia* and *Gymnobranchia* as expressive of this bipartite arrangement. Far-sighted and sagacious as must have been the views which suggested this general proposition, the word *Cryptobranchia* involves an anatomical untruth: there exists no species in which the branchiæ are internal or concealed. Respiration in all those destitute of external appendages *is* performed internally, but not by any specially constructed organs. This function, under such circumstances, devolves either upon the general walls of the alimentary canal or external surface of the body, as in the *Borlasiadæ*, *Gordiusidæ*; or it is enacted by the fluid, which, in nearly all the Abranchiate genera (except the Leech and the Earth-worm), occupies

the peritoneal cavity. One or two exceptions only can be urged against the statement that *all* Annelida breathe either by an *external* or an *internal* mechanism; in the former case special organs are nearly always provided, in the latter never. All the external branchial appendages are again subdivisible into two leading varieties, radically and essentially distinguishable. In one, the branchial organ is constructed with special reference to the exposure of the blood-proper to the agency of the respiratory element; in the other, the branchia is a mere hollow process filled with the chyl-aqueous fluid of the peritoneal cavity. Without this division, which is now for the first time submitted to the consideration of the physiologist, no correct ideas could have been formed with reference to the nature or the mechanism of the process of respiration in those genera of Annelids in which the true-blood, in proper blood-vessels, is *not* brought directly under the action of the surrounding water. Neither is it possible, without the new light afforded by this theory, to comprehend the manner in which the function of breathing is discharged in the Entozoa, in which the integuments are perfectly devoid of proper blood-vessels.

The blood-proper in the external branchia of the Annelida is distributed on two distinct plans. According to one method, a *plexus* of blood-vessels embraces the circumference of the branchial process (fig. *a*, *a*, *a*, *a*); while under the other type, the axis of the appendages is traversed longitudinally by a single blood-vessel, which at the extreme end returns upon itself. The *Nereidæ* present examples of the former type, the genera *Spio, Cirrhatulus, Eunice*, &c., of the latter (figs. 16, 18).

The body of the Annelid is for the most part vermiform in figure; it is generally cylindrical in outline, but frequently flattened, or more or less oval. It is composed of a longitudinal succession of annuli or rings, which first suggested, as already stated, the name of the class to the mind of Lamarck. In structure these rings are neither horny nor calcareous; they are always fleshy and soft. The true Annelid is distinguished therefore from the true articulated animal in the perfect absence of any approach to a hard skeleton. The segmentations are divided from each other only by a circular band of muscular fibres; the annular segments are not, as in the Articulata, perfectly distinct from each other; the longitudinal muscles pass over and under the constricting circular bands. The segmentation therefore is not real, it is only apparent. The rings form the bases of the appendages; the latter grow out of the former. The structure of each is produced laterally under various shapes to constitute the foot. The feet are never situated perfectly dorsally or perfectly ventrally, always more or less laterally. Each appendage, that is, the lateral processes of each segment, is divisible from above downwards into a dorsal and ventral half. The dorsal group of appendages is called the superior or dorsal foot, comprehending a *cirrus*, which may be flat or oar-shaped, tapering or cylindriform; a true branchia, which in shape may be a tapering lamelliform naked vascular, or cylindriform and ciliated process; and lastly *spines*, which are imbedded in the central substance of the foot for the purposes of mechanical support, and setæ or bristles, of numerously varied forms, for the purposes of locomotion or tube-making. In each foot then there is discernible,—1st, a branchial organ, which is generally developed on the dorsal moiety; 2nd, a tactile process or cirri, which are for the most part of largest size in the superior foot; and 3rd, the setæ and spines, which are constant in shape, although differing at the anterior, middle, and posterior thirds of the body. The annular segments are most distinctly marked in the middle third of the body, least so at the tail. In many genera the cirri are

extremely exaggerated at the head; this fact is exemplified in the *Syllidæ*. The tentacular cirri of the *Nereidæ* are instances of the same development. Both the fleshy and branchial appendages in the dorsibranchiate Annelids are more or less suppressed in the ventral feet.

The further study of these complex and compound organs, the appendages, will be more advantageously prosecuted under the threefold division of,—1st, the branchial; 2ndly, the tactile and locomotive; and 3rd, the setæ.

Branchial Processes.—In nearly all the species of the genus *Serpula*, the true branchiæ are grouped around the cephalic extremity, in two divisions, one on either side of the mouth; the feet in these tubicolous worms are composed exclusively of the setæ. The branchial processes are remarkably complex in their minute structure (Plate IV. fig. 11, A). Projecting in a comb-like form from the head, and tinted variously and beautifully in different species, they are admirably adapted for the exposure of the blood to the influence of the surrounding medium. Each process is supported by a camerated frame or basis (fig. 11, A, *a*), large and distinct in the back of the comb, from which are sent off, on one side only, a double row of secondary processes, corresponding to the teeth of the comb. This supporting framework is composed of an extremely delicate and flexible cartilage, the chambers of which are filled by a limpid fluid, which is in communication with that of the peritoneal cavity; an afferent and efferent blood-vessel, in parallelism, accompany this frame-structure. In the secondary processes (fig. 11, A$''$) the two vessels (b, b') are brought towards the inferior aspect, to which the vibratile cilia are in some species limited.

The cilia are large and vigorous, and cause the current, resulting from their vibration, to set strongly in the direction of the mouth. The branchiæ therefore in the genus *Serpula* are rendered at once, by virtue of their peculiar structure and situation, subservient to the two grand offices of respiration and prehension. By these sedentary Annelids, and that necessarily from the nature of, and the mode in which they obtain their food, a large quantity of water is swallowed; this circumstance suggests an explanation of the fact that in the *Serpulæ* and *Sabellæ* the *interior* of intestine throughout the rectal or posterior third of its extent, is lined by active vibratile epithelium. By the ceaseless agency of these cilia, a projecting force is imparted to the fluid emerging at the inferior orifice, which reacting against the bottom of the tube, assumes the direction of an upward tending current, and maintains the tube in the best sanitary condition, and the animal always, within and without, in contact with a constantly renewed stream of fresh water. When the animal is about to retire into its cell, the branchiæ are furled into a compact ball, which is drawn under cover of the strong membranous hood situated at the base of the branchial tuft, and the whole compressed and protected by the retracted operculum. More minutely watched, the process of furling the branchiæ discovers other refinements of mechanism. Each separate secondary process is first rolled upon itself into a minute concentric coil; this movement begins at the extreme end of each process, and rapidly creeps towards the base, at which moment the axis or vertical shaft rolls concentrically upon itself, and every trace of the gill disappears, so exquisitely perfect is the packing. By this movement of folding, both the blood-movement and the vibration are arrested. The process of unfurling is the reverse of that described (fig. 11, A).

The preceding description applies almost in every minute particular to the ultimate structure of the branchial appendages of the *Sabellæ*, in which genus these organs affect a corresponding cephalic situation,—in *Sabella à*

sang vert, *S. vesiculosa*, *S. Unispira*, and in *Sabina Poppæa**. Like those of the *Serpulæ*, the branchiæ in the *Sabellæ* and *Sabinæ* subserve the double office of determining an alimentary current towards the mouth, and of aërating the blood. *In these genera, the true-blood, in its proper vessels, is the subject of the respiratory change, and not the peritoneal fluid*; the branchiæ are organized with this express intention. This is a point of extreme interest, to which attention will be drawn under each successive species, as the description proceeds.

The genus *Amphitrite* is distinguished from the former by the distribution of the branchiæ over the dorsal aspect of the body. To this rule however exceptions occur in some species, as in *A. auricoma*, in which the branchiæ constitute comb-like appendages on either side of the third and fourth cephalic rings of the body. In *A. alveolata*, which expresses the typical structure, the branchial processes are situated on the dorsal surface of the body, except the caudal portion, on which they do not exist. They may be described as tapering, prominent, blood-red appendages (fig. 12, *a*, *a'*), carrying in their interior, axially, a single longitudinal blood-vessel, which at the distal extremity returns upon itself (fig. 12, *b*, *b'*). By Quatrefages† this vessel is figured and described as giving off lateral transverse branches, which envelope the circumference of the appendage: such an arrangement does not exist; an *appearance* leading to such an error may be readily produced by pressure. The axis of each process is hollow, and perforated by the fluid of the visceral cavity; it is along this hollow axis that the blood-vessel proceeds from the attached to the free end of the process (fig. 12, *b*, *b'*). So great is the disproportion between the quantity of blood carried by these vessels and the volume of the peritoneal fluid which penetrates the process, that in this genus also the respiratory function may be affirmed to be limited almost exclusively to the *true-blood*. A *spirally* arranged line of large vibratile cilia, coiling from the base to the apex of each appendage, provides for the constant renewal of the aërating medium (fig. 12, *a*). In *Amphitrite*, the tentacles, grouped into tufts on either side of the mouth, are organized on a plan not dissimilar from that of the branchiæ-proper. They consist of fleshy filaments, irritable and flexible in the highest degree, hollow on the axis, carrying a *single* minute longitudinal blood-vessel returning upon itself, and penetrated by the fluid of the visceral cavity. They differ from the branchiæ in the important fact of the absence of *cilia*. In *A. auricoma* the branchial combs are attached by a single root, expand and divide in a pectinated manner, each tooth carrying only a single longitudinal vessel.

This species indicates a transition from the typical *Amphitrite* to the *Terebellæ*.

In the genus *Terebella* the branchial organs appear under the form of blood-red tufts, proceeding from three separate root-vessels on either side of the occiput. The vessels divide for the most part dichotomously, forming an arborescent bunch of *naked* florid blood-vessels; each ramusculus is enclosed in a delicate cuticular envelope, *perfectly destitute of cilia*: each ramusculus is also *double*, that is, it is composed of an afferent and efferent vessel. Although extremely transparent and attenuated, the cuticular structure, embracing these branchial blood-vessels, must include some contractile fibres, since each separate ramusculus may be emptied, rendered bloodless, shrivelled, by the compression of the parietes. This provision for reinforcing

* I have constituted the genus *Sabina* to receive a new tubicolous Annelid, to be described in the sequel, which I have placed between the genera *Serpula* and *Sabella*, as having an intermediate organization. See description of species, part second.

† Organisation des Hermelles, Ann. des Sciences, 3[me] série, 1848.

the circulating powers exists in various parts of the circulating system of the Annelida. It may be affirmed generally, that in all true *Terebellæ* the branchiæ occur under the character of naked *unciliated* blood-vessels restricted to the occipital rings of the body.

In *Terebella nebulosa* they form thick rich tufts; in *T. conchilega* they are less prominent; in the small species they are scarcely visible, but in all the structure is identical.

The cephalic tentacles in the Terebellæ constitute, unquestionably, auxiliary organs of respiration, not for the aëration of the blood-proper, but for that of the peritoneal fluid, by which they are freely and copiously penetrated. They present a problem interesting alike to the physiologist and the mechanician. From their extreme length and vast number, they expose an extensive aggregate surface to the agency of the surrounding medium. They consist, in *T. nebulosa*, of *hollow flattened* tubular filaments, furnished with strong muscular parietes. The band may be rolled *longitudinally* into a cylindrical form, so as to enclose a hollow cylindrical space, if the two edges of the band meet, or a semi-cylindrical space if they only imperfectly meet. This inimitable mechanism enables each filament to take up and firmly grasp, *at any point of its length*, a molecule of sand; or if placed in a linear series, *a row* of molecules. But so perfect is the disposition of the muscular fibres at the extreme free end of each filament, that it is gifted with the twofold power of acting on the *sucking* and on the muscular principle. When the tentacle is about to seize an object, the extremity is *drawn in*, in consequence of the sudden reflux of fluid in the hollow interior; by this movement a cup-shaped cavity is formed, in which the object is securely held by atmospheric pressure; this power is however immediately aided by the contraction of the circular muscular fibres. Such then are the marvellous instruments by which these peaceful worms construct their habitation, and probably sweep their vicinity for food. The *inferior aspect* of each of these tentacles is profusely clothed with cilia, and this side is thinner than the dorsal. The peritoneal fluid, which is so richly corpusculated, and which freely enters the hollow axes of all these tentacles, is thus brought into artful contact with the surrounding water. To deny to such a mechanism the express design of aërating the organic fluid by which they are distended, were indeed to argue against the strongest probability. The minute blood-vessel which runs in the hollow axial space along the whole extent of the filament is so disproportionately small in comparison with the volume of the peritoneal fluid by which this space is filled, that the former cannot reasonably be supposed to share in the respiratory function of these organs. In addition to the two important uses already assigned to the tentacles in the *Terebellæ*, they constitute also the real agents of locomotion. They are first outstretched by the forcible injection into them of the peritoneal fluid, a process which is accomplished by the undulatory contraction of the body from behind forwards; they are then fixed, like so many microscopic cables, to a distant surface, and shortening in their lengths, they haul forwards a step or two the helpless carcass of the worm.

In *T. conchilega*, the cephalic tentacles are inferior to those of the former species in number and size; they are also differently configurated. They approach the prismatic in outline; in transverse section they present a triradiate shape. In minute structure, mechanism of action and uses, they coincide in the most exact manner with the tentacles of *T. nebulosa*. It is not a little curious that in the *Terebella*, these organs, which are homologous with true cirri, should be so richly provided with vibratile cilia, while the true-blood branchiæ are entirely destitute of these motive organisms. Nothing

but the view propounded in this memoir, with reference to the share taken by the peritoneal fluid in the function of respiration, will enable the physiologist to reconcile this apparent incongruity.

The dorsibranchiate order comprehends a considerable proportion of the class Annelida. Of them, Cuvier remarks, "Ont leur organs et surtout leur branchies distribués à-peu-près également le long de tout leur corps, ou au moins de sa partie moyenne." In the Cuvierian arrangement, at the head of this order stands the genus *Arenicola*. Respiration is performed in *Arenicola Piscatorum* by means of naked blood-vessels, projecting at the root of the setiferous process upwards and outwards one-fourth of an inch in the adult worm from the surface of the body (fig. 13). They are limited in number and distribution to the fourteen or sixteen middle annuli of the body. They are commonly described as forming an arborescent tuft; the division of the vessels is however regulated by a fixed principle. When fully injected with blood, the vessels of each branchia form a *single* plane (fig. 13), rising obliquely above and across the body, and immediately behind each brush of setæ. In the adult animal each gill is composed of from twelve to sixteen primary branches (fig. 12, *a*, *a*), proceeding from a single trunk, which arises from the great dorsal vessel; the vessels in the branchial tuft describe *zigzag* outlines; the secondary branches project from the salient point, or the outside of each angle of the zigzags; and the tertiary from similar points on the secondary branches. This mode of division, occurring in one plane, and in all the smaller branches, results in a plexus of vessels of extreme beauty of pattern or design. Each branchial tuft, and each individual vessel possess an independent power of contraction; in the contracted state the tuftalmost entirely disappears, so completely effected is the emptying of the vessels. The contraction, or *systole*, in any given tuft occurs at frequent but irregular intervals; this movement does not take place simultaneously in *all* the branchiæ, but at different periods in different tufts. As there is no heart-like dilatation in the afferent vessels of the branchiæ (fig. 10, *f*, *f*), the contractile power with which the exposed branches are endowed, becomes an important means of reinforcing the branchial circulation. The vessels appear quite naked, and if examined in the living state, each ramuscule seems to consist only of a single trunklet; if this were really the case, it would of course resolve itself into a tube ending in a cul-de-sac, and the blood movement would be a flux and reflux; but by injection it is easy to show that the finest division of the branchial arbuscle contains a *double* vessel (fig. 13, B), enveloped in a common muscular, although extremely diaphanous sheath. That these vascular sheaths, which are only fine productions of the integuments, are furnished with *voluntary* muscular fibres, is proved by the rapid and simultaneous retraction of *all* the branchiæ into the interior of the body, which follows when the animal is touched. This sheathing of the blood-vessels with true muscular coats is a frequent character of the circulating system of the Annelida; it is a power which compensates the absence of a heart. It is extremely interesting to watch in the young *Arenicola*, the manner in which one little blood-vessel after another, in the progress of growth, shoots slowly from its stock-branch. In *Arenicola*, as in *all* Annelida in which the vessels of these organs are naked, the branchiæ are destitute of vibratile cilia. It will be found that under such circumstances, viz. when the branchial vessels occur as naked projections from the external surface, the description now given of these organs in *Arenicola* will apply in every minute respect of structure to all other Annelida. It will prove exact in relation to the *structure* of the branchiæ in the several species of the beautiful genus *Euphrosyne* of Savigny. In *E. foliosa* (M. E.) the branchial vessels form larger and richer tufts, having

a similar situation in relation to the setiferous feet. These organs assume the same character in *E. laureata* (S.). The elegant worm described by Audouin and M.-Edwards* is furnished with branchial organs in form of arbuscles of naked vessels, after the pattern of those of the dorsibranchiate Annelids now described. Under the genus *Amphinome*, occurs *Plerone tetraëdra* (of Savigny), in which the breathing organs assume the form of larger florid bunches of naked blood-vessels, situated on the dorsal aspect of the body, each tuft being protected in front by a bundle of strong bristles. These organs assume a still more beautiful form in *Chloeia capillata*, in which the division of the vessels occurs on the bipinnate principle.

The genus *Eunice* presents another and different type of branchial vessels. Arranged in a prominent row of bright vessels, standing erect as minute combs at the dorsal base of each foot in the body, the branchiæ impart to all the species of this genus a graceful and characteristic appearance. In every species the branchial vessels divide on a uniform plan *peculiar* to this genus. The primary trunk rises vertically along the inner side of the branchia, and sends off from its outer side, at intervals, *straight* vessels, which gradually decrease in size from below upwards: each branch forms a straight undividing vessel, curving gently upwards and towards the median line: these branches become in their number characteristic and distinctive of species. In some of the smaller species inhabiting the British coasts, the branchiæ are composed only of a single vessel; this is the case also with the *young* of the larger species; in others they vary from the single vessel to the number of six and eight. In *Eunice gigantea*, according to the figures of Milne-Edwards, the vessels of each branchia amount to thirty-six in number. These vessels, although perfectly naked and unciliated, like those of *Arenicola*, are both less contractile and retractile; they extend in this genus from the head to the tail, and equal in number the annular segments of the body. In the dorsibranchiate genera, the branchial organs of which have now been described, the true-blood circulating in its proper vessels, has been proved to be *exclusively* the *seat* and *subject* of the respiratory process. The fluid of the peritoneal cavity, abundant in quantity, and highly organized though it be in the genera just reviewed, does not in the least degree participate in this great function. Judged by such a test, the genera of this grand order of worms should be marshalled under two primary groups, of which one (embracing the preceding species) would comprehend those in which the function of breathing devolves *exclusively* on the *true*-blood, while the other would be characterized by the fact that the branchiæ are organized such as to permit more or less completely the exposure, in conjunction with the blood-proper, of the chyl-aqueous fluid of the visceral cavity, to the influence of the surrounding aërating element. It will be seen in the succeeding description, that when the branchial apparatus is penetrated thus by two separate and distinct fluids, coordinate probably in organic properties, the vascular system of the body generally will be found by so much the less developed by how much the peritoneal fluid supplants the blood in the branchiæ. The structure of the branchial organs becomes thus a significant test of the position of any given species in the Annelidan scale,—those being entitled to the highest rank of which the respiratory organs are exclusively designed for the exposure of the blood-proper to the action of the oxygenating medium, those to the lowest in which the peritoneal fluid alone circulates in the branchiæ. The subgenera *Lycidice*, *Aglaura*, and *Œnone*, of the genus *Eunice*, are distinguished in the circumstances now defined, from all the former genera of the dorsibranchiate order. Naked, unciliated blood-vessels no longer in

* See Cuvier, Règne Animal, *Annelides*, pl. 8.

them form exclusively the branchial organs: loose and large-celled tissue is superadded to the proper blood-vessels, which are far less in relative size than those in the former variety of branchiæ; into the cells of this tissue the fluid of the visceral cavity insinuates itself, its course being marked by a slow motion. There exists however another point of structural difference between the branchial organs of this group and those of the former; this difference admits of the following general expression,—that wherever the fluid of the peritoneal cavity is admitted into the interior of the branchial organs, the latter are invariably supplied more or less profusely with vibratile cilia.

In the genus *Lycidice* the branchia consists of a flat, lanceolate process, more or less developed, surrounded marginally by a blood-vessel, the mid-space between the lines of the advancing and returning vessels being composed of large-celled tissue, lacunose, into which the peritoneal fluid penetrates by a flux and reflux movement. The branchiæ in *L. Ninetta* are situated dorsally, and are supplied at their bases with single rows of vibratile cilia. Those of *Aglaura fulgida* are similarly constructed, although they differ slightly from those of the former genus in size and figure. In *Œnone maculata* they occur under a more developed form, constituting flattened, pointed trowel-shaped processes, the plane of which is vertical with reference to that of the body. A blood-vessel, as in the former cases, trends along the borders, immediately beneath the cuticle. The course of these vessels is followed by a row of large and prominent vibratile cilia.

In the branchial system of the genus *Nereis* (Cuv.), *Lycoris* (Savigny), the minute anatomist encounters a structure strikingly different from anything hitherto described. Whether round or laminated, the true branchiæ in this genus are always penetrated by the fluid of the visceral cavity, and the blood-vessels assume a peculiar disposition. When the branchial process is conical in shape, its base is embraced by a *reticulated* plexus of true blood-vessels (fig. 14, *a, a, a, a*), which is situated quite superficially and immediately beneath the epidermis. These vessels are most prominently developed on the dorsal-most process, which therefore may be called the branchial, but they extend more or less over all the cirri. A better characteristic of the branchiæ, both the conical and the foliaceous, in the *Nereids*, is that of their being penetrated by the peritoneal fluid. In those species in which the branchial process is round, the interior of the base is hollow, and filled with the fluid of the visceral chamber. Floating in this fluid may be seen, when viewed transparently, coils of naked blood-vessels; in those in which they are laminated or foliaceous, as in *Nereis renalis*, the step of the exterior surface does not extend beyond the limits of the base, the flat portion, however, tunnelled by straight spacious canals (fig. 14, *b, b*), which radiate with great regularity from the base to the expanded circumference of the process. In these canals the corpuscles of the peritoneal fluid may be seen rolling to and fro, advancing and returning in the same channel. These movements are regulated by those of the great current in the chamber of the peritoneum. This type of structure prevails in *Nereis renalis, N. longissima*, and in a slightly modified form, in consequence of the less flattened shape of the branchiæ, in *N. viridis*. The *round* variety of branchial processes obtains in *N. margaritacea, N. Dumerillii, N. fucata, N. pelagica*, and *N. brevimanus*. It is a fact difficult to explain that the branchial organs in the *Nereids* should be destitute in every species of vibratile cilia.

The laminated or foliaceous type attains the point of its maximum development in the branchial appendages of the genus *Phyllodoce* (fig. 15). It was difficult to assign any other than a respiratory use to the rich, leaf-like projections in these beautiful worms. In the absence of all ideas

tending to a knowledge of the nature and capabilities of the fluid contents of the visceral chamber, the real meaning of the radiating channels (fig. 15, *a*, *a*, *a*) by which the respiratory laminæ are perforated, and therefore of the mechanism of the function of which they are the scene, never could have been rightly apprehended. It was only by mistaking the peritoneal fluid for blood that the branchial office of these appendages could have been predicated, and this very mistake has been committed by M. Quatrefages. The branchiæ in *Phyllodoce viridis* are prominent dorsal appendages: in this worm the blood-system can be traced only by a few scanty vessels distributed over the roots of these processes; nor are the canals very spacious and distinct; they are more like lacunæ in a spongy tissue. In *P. bilineata* and *P. lamelligera*, the radiating passages, distinct from each other, and communicating only indirectly through cells, are extremely obvious under the microscope (fig. 15, *a*, *a*, *a*). They carry the fluid of the peritoneal cavity, the corpuscles of which may be seen flowing and ebbing in the same channel. Nothing can, however, more conclusively prove the true branchial character of these laminæ than the presence of cilia, the vibrations of which can be observed only at the edges of the respiratory laminæ. These are best seen in *P. lamelligera*. This is a striking point of distinction between the *Phyllodoce* and the *Nereids*, in which vibratile cilia on the branchiæ have no existence. The peritoneal fluid then may now be affirmed as that, in the œconomy of the *Phyllodoce*, which is the subject exclusively of the respiratory function, the true blood receiving its supply of oxygen from this fluid, afterwards to convey it to the solid structures of the body.

In the genus *Glycera* the blood-proper is entirely excluded from the organs of respiration. This office devolves exclusively on the chyl-aqueous fluid, which in nearly all the species of this genus is profusely supplied with *red* corpuscles. The gills consist of hollow cylindrical appendages (fig. 16, *a*), emanating from the base of each dorsal foot at its superior aspect, filled in the interior with the fluid of the visceral cavity; but, what is remarkable in the structure of these organs and quite peculiar to this genus, is that the *interior* parietes of the cylindrical hollow of the branchiæ is lined with *vibratile cilia*; these motive organules cause the corpuscles of the fluid by which the branchiæ are penetrated, to move with great rapidity in a definite direction, viz. peripherally on one side and centrally along the other, each corpuscle whirling on its own own axis as it proceeds. Ciliary vibration cannot be detected on the outside of the branchial appendage.

It is a feature of structure more strikingly illustrated in *Glycera* than in any other Annelid, that whenever the peritoneal fluid is the subject of the respiratory function, it is brought into the branchial organ in much greater relative proportion than the blood-proper when *it* is the subject of this process; and the branchiæ are always constructed in adaptation to this difference.

In the *Syllidæ* the branchial organs (fig. 17) are penetrated only by the peritoneal fluid, but it can be detected in motion only in the *bases* of the feet, and these parts only are furnished with vibratile cilia, which are large and active. The long filiform and, in some species, moniliform appendages which are described commonly as the branchiæ of these worms, have *no* central hollow (fig. 17, *a*); they are filled with large-celled tissues through which the *fluid* parts of the contents of the visceral cavity slowly penetrate. But in the spacious chambers occupying the bases of the feet (fig. 17, *b*), a whirlpool of the peritoneal fluid may be readily observed. The structure now described is very perfectly typified in *S. prolifera*; the moniliform variety is best seen in *S. armillaris* and *S. maculosa*. A similar confirmation prevails in the genera *Ioida* and *Psamathe* of Dr. Johnston. In the Syllidan family,

which excels all others in grace and beauty, the proper blood-system is almost indetectable, in consequence of the colourlessness of the contents. It may be stated with confidence that blood-vessels do not enter into the structure of the branchial processes. The respiration therefore devolves exclusively on the chyl-aqueous fluid.

Amongst the family *Ariciadæ*, first defined by Audouin and Milne-Edwards, several other varieties in the configuration of the breathing organs occur. In the genera *Leucodore, Nerine* and *Aricia*, the branchial appendages affect a dorsal situation. In every species they are traversed from base to apex by a single blood-vessel returning upon itself (fig. 18, *a*). This vessel, however, is supported by a lobule of spongy tissue (fig. 18, *b*), into the cells of which the fluid of the visceral chamber penetrates. The office of respiration in this family is therefore discharged in part by the blood and in part by the chyl-aqueous fluid. In every species of this family the branchiæ are supplied by vibratile cilia having a distinct disposition in each. *Lincodore ciliatus*, on the dorsal aspect, and over the posterior two-thirds of the body, is covered on either side with a row of flattened conical branchial processes, blood-red in colour and richly ciliated. They are largest anteriorly and smallest near the tail. The cilia are disposed in a spiral line from the attached to the extreme end. Viewed with a high magnifying power, and transparently, a camerated axis, composed of exquisitely fine hyaline cartilage, may be discovered, fulfilling on the branchiæ of this elegant little boring Annelid the office of mechanical support, as a similar structure was formerly shown to do in those of the *Sabellæ*.

In the genus *Spio* or *Nerine* the respiratory organs occur under forms of the highest beauty (Plate V. fig. 18). They constitute flat, membranous, penknife-shaped appendages, curving gracefully over the back with the curve of the "ring" of the body by which they are supported, and crossing over the dorsal median line and alternating with the corresponding process of the other side. The *plane* of each process is vertical in relation to the longitudinal axis of the body; they lie therefore one over the other in an imbricate manner. They are less flat and close in *N. vulgaris* than in *N. coniocephala*. They are largest in size towards the middle of the body; smallest anteriorly and posteriorly. The blood-vessels, the afferent and efferent (*a*, fig. 18), run close to and parallel with the inferior border of the process; the upper part of each is composed of a membranous lobular addition to the inferior and vascular portion. Into the cells of this lobule the chyl-aqueous fluid slowly finds its way, and participates obviously in the office of respiration. In *N. coniocephala* it is remarkable that the cilia should be limited in their distribution to the margin along which the true blood-vessel runs. This fact is less manifest in *N. vulgaris* in consequence of the smallness of the membranous lobule. In *Aricia Cuvieri* the branchial appendages are more conical in figure, more vertical in position, and developed only at the posterior four-fifths of the body. They are covered with large vibratile cilia, which likewise extend over that segment of the dorsum which separates the bases of the branchiæ. Like those of the preceding genera, they are supplied with spongy tissue (fig. 18, *b*) for the exposure of the peritoneal fluid*. It may have been remarked that in all the members of the preceding family the real branchial organ has consisted of an evolved or exaggerated development of the *superior* element of the dorsal foot. In the genus *Nephthys*, which comes now under review, it is the inferior element of the dorsal foot which becomes the subject of this evolution. *Nephthys Hombergii* of our coasts

* I have described a species of *Aricia* in which these branchial organs are entirely suppressed.

is a remarkably vigorous and active worm, and yet its organ of breathing consists only of a comparative small *curved* ciliated process, situated under cover of the dorsal foot, and carrying only a single-looped vessel. It may be mentioned as an interesting proof of the real appropriation of this process in *Nephthys* to the function of breathing, that the *same* process, although *similarly shaped*, on the ventral or inferior foot, is *not* provided with cilia, nor is it penetrated by any blood-vessel.

The genus *Cirrhatulus* of Lamarck, and the allied group constituted by Savigny under the name of *Ophelia*, introduces to the physiologist another modification of the branchial organs within the limits of the dorsibranchiate order. As in the preceding families, they are in these latter only '*developments*' of the dorsal cirri. In *Cirrhatulus Lamarckii* (fig. 19, *a*, *a*), a linear series of yellowish, and blood-red threads, remarkably irritable and contractile, project to a considerable distance, from either side of the body, throughout its whole length; at the occiput, however, they are arranged in a crown-like form. These beautiful filaments, which are obviously designed to fulfil the twofold office of touch and respiration, appear under the microscope to consist only of a single blood-vessel enclosed in a delicate sheath of integument. Closer analysis, however, discovers *two vessels* (fig. 19, a'') in each of these filaments, and traces of longitudinal and circular muscular fibres in the investing sheath. By the contraction of this sheath, the enclosed vessels may be completely emptied of their blood from one end of the filament to the other. This contraction does not take place simultaneously in every part, but undulatorily, the wave motion beginning at the extreme fore-end. It is especially to be noted, that, in this variety of appendage, in which the respiratory is only an incidental function, there exist *no vibratile cilia*. These organs in *Ophelia coarctata* exhibit analogous characters, while they are less numerous and much shorter*. The *Aphroditaceæ* constitute a group of Annelids to which the term "dorsibranchiate" by no means correctly applies; that is, in the majority of the species embraced in this order no branchial appendages exist either on the dorsum, or any other part of the body. Respiration is performed on a novel principle, of which no illustration occurs in any other family of worms. In all *Aphroditaceæ* the blood is colourless. The blood-system is in abeyance, while that of the chyl-aqueous is exaggerated. Although less charged with organic elements than that of other orders, the fluid of the peritoneal cavity in this family is unquestionably the exclusive medium through which oxygen is absorbed. The true Aphrodite type of respiration occurs in *Aphrodita aculeata*. In this species the tale of the real uses of the 'elytra' or scales is plainly told. Supplied with a complex apparatus of muscles, they exhibit periodical movements of elevation and depression. Overspread by a coating of felt readily permeable to the water, the space beneath the scales during their elevation becomes filled with a large volume of *filtered* water, which during the descent of the scales is forcibly emitted at the posterior end of the body. It is important to remark that the current thus established *laves only* the *exterior* of the dorsal region of the body. It nowhere enters the internal cavities; the latter are everywhere shut out by a membranous partition from that spacious *exterior* enclosure bounded above by the felt and the elytra. In this species the peritoneal chamber is very capacious, and filled by a fluid which only in a slight degree contains organized particles. The complex and labyrinthic appendages of the stomach lie *floating* in this fluid, and in the chambers which

* I have recently discovered several new species in which the branchiæ assume the filiform shape and structure as described in the text, and of which the position in the Annelidan scale should be near that of *Cirrhatulus*.

divide the roots of the feet. From this relation of contact between the peritoneal fluid and the digestive cæca, *which are always filled by a dark green chyle*, it is impossible to resist the conclusion that the contained fluid is really a *reservoir* wherein the oxygen of the *external* respiratory current, already described, becomes accumulated. From the peritoneal fluid the aërating element extends in the direction of the cæca, and imparts to their contents a higher character of organization. These contents, thus prepared by a sojourn in the cæca of the stomach, become the direct pabulum for replenishing the *true* blood which is distributed in vessels over the parietes of these chylous repositories. The sequence of events now indicated will convey to the mind of the physiologist a clear idea of the mechanism of the processes both of respiration and sanguification. It cannot have escaped observation that there prevails a striking resemblance between the general anatomy of *Aphrodita aculeata* and that of the Asteridæ among the Echinoderms. The point of junction thus established between the Echinoderms and Annelida is as obvious and natural as that which exists between the *Sipunculidæ* and the *Nemertinidæ*. It is thus constantly observed by the philosophical anatomist that in the animal kingdom adjacent classes are linked together into a continuous series at *more* than one point.

In the genus *Palmyra* no *external* respiratory appendage is provided; although the *feet* of the Aphrodite are absent, the *elytra* in the elegant *Palmyra aurifera* generate a true branchial current.

This observation is also true of the family of the *Polynoë*. These worms are destitute of external branchial processes. The fleshy cirri, by which the *true* respiratory appendages of *Sigalion Boa* are represented in the *Polynoë*, are *solid, not hollow and ciliated*, and further situated only on every third or fourth foot. The fluid of the peritoneal cavity in these worms is voluminous; it is little corpusculated, like that of *A. aculeata*, and moreover the stomach in the genus *Polynoë* is more or less extended laterally in form of diverticula. The organisation of the familiar Sea Mouse therefore conveys exact ideas with reference to the principles of structure on which nearly all the scale-clad worms are formed. In all 'the scales' are mechanical, and very skilfully contrived instruments for generating true branchial currents. In *Sigalion Boa*, however (fig. 20, *a*), which is a worm considerably more elongated than the *Polynoë*, an exception occurs to the principle observed in the other scale-clad worms; *i. e.* express external organs of respiration are provided. They exist under the character of hollow, cylindrical and curved appendages (fig. 20, *a*) emanating by a mammilla under cover of the scales, and projecting a short distance beyond their outer edges. These processes are profusely lined *within*, but not *without*, by vibratile cilia. The corpuscles of the peritoneal fluid may be readily brought under the eye, while whirling in the interior. In *Polynoë semisquamosa*, Williams (fig. 21, *a*), a flat appendage is added to the base of the foot, presenting radiating canals for the exposure of the peritoneal fluid. It is thus then established by direct demonstration, that the fluid contained in the great visceral cavity is the real and exclusive subject of the process of oxygenation in these scale-armed Annelids. If this fluid consisted only of pure water, that is, if its specific gravity were identical with that of the external element, those conditions would exist which are least favourable to the interchange of oxygen and carbonic acid. It is therefore no departure from cautious reasoning to infer that the oxygen received into the peritoneal fluid exerts upon the elements of the latter the effect of *raising* them in the scale of organic fluids, and of preparing them for the work of solid nutrition.

It now remains to consider the mode in which the process of breathing

is accomplished in the *Abranchiate* Annelids. Of this division of worms, it is stated in all systematic works that the function of respiration devolves on "the external cutaneous surface of the body," and this is regarded as expressing the principle on which the same function is performed in all Entozoa. It will be afterwards proved that between *some* species of *Abranchiate* Annelids and *some* species of Entozoa there really does obtain almost an identity of structure, under a striking diversity of external form. In the Entozoa, however, the space between the peritoneum and integuments is much larger than in the corresponding species of Abranchiate Annelids. The difference affects materially the *mechanism* in the two cases of the respiratory process. The Entozoa are remarkable for the large amount of the peritoneal fluid; the true blood-system being in proportionate abeyance. In the Abranchiate Annelids, the system of the peritoneal fluid is suppressed proportionately to the greater development of that of the blood-proper. Here, as in other Annelids, the proportion between the system of the chyl-aqueous fluid and that of the true-blood is observed to be *inverse*.

It may be affirmed as a law of the organization in all abranchiate worms, that the system of the blood-proper is more developed on the parietes of the intestinal canal than on the integuments. This fact, *wherever* the *peritoneal space* is obliterated by the adherence of the intestinal cylinder to that of the integument, transfers the office of respiration from the latter to the former region; that is, as is practically demonstrable in the instance of *Nais filiformis*, the large volume of water which is incessantly streaming throughout the length of the alimentary canal, holding atmospheric air in solution, while it ministers by its organic particles to the nutrition of the system, contributes also by the *air* with which it is mixed, to the great purpose of aërating the living fluids of the organism. This is accomplished partly by the exosmose of the dissolved air from the *intra*-intestinal into the peritoneal or extra-intestinal space; and partly by the absorption of it into the true-blood circulating in the vascular plexus by which the intestinal parietes are embraced. In the Entozoa it is not improbable that more of the aërating element is derived by the peritoneal fluid *ab extra*, from the medium on which they are parasitic, than *ab intra* from that which they swallow. Whichever of these two great systems of the body (intestinal and integumentary) be entitled to the greater share in the process of respiration in the Abranchiate Annelids, it should be remembered that in the Entozoa the *structure* of the integuments is almost entirely destitute of true-blood-vessels. This fact renders the inference probable, that the partition of the integuments, which in the Entozoa is *thin*, is permeated by the gaseous elements without, and that they thus *enter*, without meeting much of the true-blood *in transitu*, into the fluid of the visceral cavity, by which it is brought into contact with the solids of the body.

In the genera *Lumbricus* and *Hirudo*, the peritoneal fluid and space being very small, the function of breathing falls on the *united* structure of the intestine and integument. These two genera are remarkable for the great development of the reproductive organs, which occupy, to crowding, the interval of the peritoneal cavity; and for the excessive elaboration of the system of the blood-proper.

The genus *Trophonia* is characterized, as compared by the former, by an increase in the volume of the contents of the peritoneal fluid. Here also all traces of external branchiæ are wanting; life is maintained through the aërating influence of the chyl-aqueous fluid.

In the *Naides*, observation proves beyond doubt, that breathing is accomplished through the medium of the peritoneal fluid; its movements are

rapid, and composition highly organized; in every sense it is organically and chemically qualified for the discharge of this function.

By Audouin and Milne-Edwards, in this place in the Annelidan series is placed the anomalous genus *Clymene*. No attempt has been made by these distinguished authors to unravel the anatomy of these eccentric worms. On the head and body no vestige of external appendage (except the hooks) is discoverable. At the tail, however, irregularly scalloped, membranous processes may be observed, which are in every essential respect to these worms, what the cephalic processes in them are to the *Sipunculidæ*; that is, they are *hollow* membranous projections of the peritoneal cavity, admirably adapted to expose the contents of this cavity to the influence of the surrounding medium. A blood-vessel or two may be traced at the roots of these processes, being only enough to prove that the system of the blood-proper in these Annelids is very insufficiently developed to enact the great function of respiration. The branchial processes of the *Clymenidæ* are *not* provided with *cilia*; they afford the only illustration in the class Annelida of branchial organs specialized around the *outlet* of the alimentary system.

It has now been shown that the branchial organs in the Annelida arrange themselves under two leading divisions, between which a clearly legible line of demarcation exists. Under one of these divisions, the *blood-vessels* bearing branchiæ occur; under the other, those organized for the exposure of the chyl-aqueous fluid. It was formerly demonstrated in detail that this fluid, in larger or smaller volume, and in proportions varying in different species relatively to those of the true-blood system, occurs in nearly every known Annelid. When the contents of the latter are well exposed to the agency of oxygen, no provision in general exists for the exposure of the former fluid; and conversely, when the appendages designed for the office of breathing are constructed with especial reference to the outspreading of the former to the aërating medium, blood-vessels are seldom found to enter into their structure. It is probable therefore that in the œconomy of the Annelid these two fluids are co-ordinate elements; they are convertible proximate principles; they exhibit equal physiological capacities; both are capable of discharging the function of respiration, and both are capable of supplying the solids of the body with the materials of increase.

Locomotive and tactile appendages.—The cirri and setæ of the feet are included under this head. The former admit of subdivision into two varieties, of which one may be classed as the natatory and the other as the tactile. The setæ, constituting in many species appendages to the body, of the most brilliantly ornamental character, are always important mechanical means of locomotion. *Sensation and locomotion* are thus in the Annelida provided for by means of organs of elaborate construction. So numerously and interestingly diversified in number, proportions, and form, are these several parts of the feet, that a detailed description of them becomes here necessary in order that what is most characteristic in the anatomy of species may be fully expounded. That element of the foot which is dedicated to the function of breathing has already been made the subject of minute inquiry. Under the present head therefore the *branchiæ* will receive no further notice.

The *branchiæ* and operculum which plume so richly the head in the genus *Serpula*, are endowed with extreme sensibility. This provision supersedes the necessity for fleshy tactile appendages to the body, which is enclosed by the calcareous tube in which the worm lives: in structure and curvature these tubes differ in different species. The interior is smooth, not so smooth however as to be slippery, nor so hard as to render difficult or impossible the *fixing* of the hooks and bristles of the feet, by which the animal is enabled to

rise or descend at will. The body of the *Serpula* is obviously distinguished into two parts, of which one may be called the thoracic, and the other the abdominal. The former is provided with prominent feet, powerfully protrusile, and a system of strong bristles (Plate VI. fig. 22, *a*), which during the movement of the feet run to and fro in the axes of the feet. On the *dorsal* aspect of these appendages, a row of microscopic hooks, marked by a minutely dark line, extending transversely in part round the body, may be discerned (fig. 22, *b*). It is by aid of these inimitable instruments that the worm grasps the interior of the tube. They are wielded by means of long thread-like tendons, fixed on artful mechanical principles, to the attached end of each hook. During the action of the muscles, of indescribable delicacy, the hooks are projected to some distance beyond the plane of the surface on which they repose in the inactive state. These singular organs are formed after the pattern of the common "bill-hook" of farmers, having the *edge* deeply notched into *teeth*, directed downwards. Through the agency of these hooks the worm is enabled to withdraw itself into its tube with extraordinary precision, rapidity, and muscular force. In this movement, arithmetic would fail to compute the number of these instruments, which is simultaneously extruded: their office is *exclusively* that of pulling the animal back into its cell. Gifted with such marvellous instruments, and alarmed by external danger, these elegant Annelids will retreat with the rapidity of lightning. The advance movement, in which it *pushes* itself out of its tube, is of course the reverse of the former; but what is remarkable is, that this movement of emergence is performed by means of organs quite distinct and different from those used in the act of retreating. In principle of action and construction, these instruments are strikingly dissimilar—one is a *pulling* and the other is a *pushing* machine. The setæ or bristles, which are protrusile, are the pushing organs (fig. 22, *a*). Nothing in nature is so perfect as the adaptation with which these organules are fitted for the end in view. Each *seta* is composed of a strong rigid and unresisting shaft, and an expanded shoulder, drawn out into a point. On one side of this pointed shoulder may be remarked a double row of serrations which are admirably calculated to *catch* against the surface of contact, forming thereby a firm and fixed point of propelling force. Computing the *pushing* force which each seta is capable of exerting, and multiplying this amount by the number of setæ in each foot, and this again by the number of feet with which the worm is provided, a conception may be formed of the aggregate of mechanical power with which the animal executes its "march forwards." A similar calculation applied to the hooks, will give a correspondingly prodigious resultant of power for retreat. The mechanical principles thus imperfectly expounded, will correctly apply in every particular to the instances of all tubicolous worms; the hooks perform one movement, the bristles another. Never before has the *meaning* of these matchless instruments been differentially defined. The hooks and the bristles are characteristic and distinctive of species. By one single microscopic hook or seta, visible only under the *highest* powers of the microscope, the naturalist may pronounce the species, and mentally reconstruct the individual—no mean triumph for the science of observation! In the Serpulidans, as in all the fixed tubicolous Annelids, the feet near the tail, acting therefore at the bottom of the tube, are modified in structure with express reference to the duties of mopping, sweeping, scraping, and wiping the cæcal end of the habitation. The organs for the discharge of these necessary household duties will be afterwards described more at length in the Amphitritans.

The *Sabellæ*, like the *Serpulidæ*, are tubicolous; the tubes of the *Sabellæ*

are however soft, tenacious, flexible, and muddy. Slimy mucus, furnished by the integumentary glands of the body, is the mortar or cement, fine sand-molecules are the 'stones' or solid material of the architecture. In the *Sabellæ*, the *lime* of which the tubes are built is held in solution in the mucus provided by the cutaneous glands. It is adjusted in the fluid form, and moulded by appropriate tools into the required shape: *it then solidifies*; solidifies too *under water*, like the "*Aberthaw lime*!" The tube of the *Sabellæ* fits closely round the body of the worm; it is slightly elastic, and the interior is smooth.

It is a fact of singular mechanical interest, that the *thoracic feet*, which vary in number in different species, are disposed in a manner which is the exact reverse of that in which the *abdominal* are arranged; the latter being distributed over the posterior $\frac{7}{8}$ths or $\frac{4}{5}$ths of the body. This remarkable provision confers manifestly on the inhabitant of the tube, which is frequently unattached except at its inferior end, the power of *rolling* on its own axis, of *turning* round, in order that it may sweep with its branchiæ in search of food and fresh portions of water, the whole circumference of the circle. This disposition of the thoracic feet on the dorsal aspect of the body, while the abdominal are placed on the ventral, with a simplicity of mechanism perfectly wonderful, arms the worm with the means of *fixing* the tube whilst it executes its complex movements. If all the feet were disposed on the *same* side of the body, this important object, it must be at once obvious to the mechanician, never could be accomplished. The worm would be a palsied prisoner in its self-constructed cell.

The brushes of setæ in the thoracic feet point dorsally, and the row of hooks extend from their bases in the direction of the dorsal median line. The brushes of the abdominal feet point ventrally, and the row of hooks extend from their roots transversely in the direction of the ventral median line. It is evident then that these classes of feet must act in opposite directions. The hooks slightly vary in form in different species, but the setæ in all the species are constructed on one plan (fig. 23, *a*). In *Sabella à sang vert* (M. Edwards), the hooks (fig. 23, B) are formed by the turning of a finely sharp beak very much upon itself, the attached end or root expanding into a broad base. From this latter part a very curious claw-like process, surmounting a straight shaft, proceeds (fig. 23, B), the use of which must consist in *tightening* the tube *after* the hook has been fixed, and that to render the *hold* of the latter more secure. The *setæ* present a leaf-like form, and margins strongly toothed (fig. 23, *a*). Composed of an unyielding horny material, they are admirably fitted for pushing; the feet in these, as in other worms, act in obedience to the principle of the composition of forces. The forces meeting and uniting in the ideal axes of the body, or rather in the centre of the body of the animal, produce a resultant expressed by its motion *forward*.

In *Sabella vesiculosa* (Montagu), the hooks are formed somewhat differently. The broad bases observed in the former instance, are replaced by a tapering curved end to which the muscle is attached (fig. 23, B). The feet are similarly distinguished into thoracic and abdominal: the setæ are constructed upon the same precise type. The same disposition of the feet prevails in *Sabella unispira* (M.-Edwards); here, however, the bases of the hooks are broad, and the claw-like process described in *S. à sang vert* reappears. The setæ preserve the type of construction characteristic of the genus.

The feet in *Terebellæ* are composed only of hooks and setæ. The soft appendages are transferred to the head, where, under the form of tentacles, they assume an extreme degree of development. A full statement of the history of these remarkable organs has already been given.

The *Terebellæ* differ from the *Sabellæ* in the uniformly abdominal position of the feet and rugæ for the hooks. Since the tube is *fixed*, this arrangement entails no inconvenience. In another essential respect the *Terebellæ* are distinguished from the *Sabellæ*. In the former the cephalic tentacles are powerful *manual* appendages, uniting in themselves the threefold office of touch, prehension, and *pulling*; for it was shown that through their aid the animal assists the operation of the hooked and setiferous feet in drawing itself forwards; in the *Sabellæ*, the cephalic appendages are quite incapable of any, the slightest motive act; they are exclusively branchial. The duties of locomotion therefore in this latter genus devolve exclusively on the feet. In the *Terebellæ*, the setiferous feet are limited to the anterior end of the body; the posterior presenting the form only of hook-armed ridges. In *Terebella nebulosa* these feet amount to twenty-three in number; the setæ with which these feet are furnished, are simple or unserrated lancet-shaped and flattened hairs. The feet themselves are capable of only slight extrusion beyond the plane of the body, serving more the purpose of trowelling, plastering, and polishing the interior of the tube, than of moving the animal in its cell. The hooks (fig. 24), in nearly all species of *Terebellæ*, are disposed in double rows on the dorsum of each ridge. This arrangement exists invariably on the "ridges" of the posterior $\frac{3}{4}$ths of the body; on the anterior setiferous portion they are often in *single* rows. It is evidently designed as a means for firmly *fixing* to the tube the tail end of the body, in order that *upon it as a pivot*, the anterior portion and the head may enjoy perfect freedom of motion. Considering the extreme power of elongating and contracting the body with which these ornamental worms are gifted, it is mechanically clear, that upon such a basis a great range of movement is secured. The hooks themselves are furnished with one long and large tooth, and several smaller ones above the former; the back presents a projecting spine, to which a tendon is attached, the office of which is to *un*grasp or loose the tooth from its hold, and which may be called the *laxator hamuli*. The attached conical base of each hook is furnished with another tendon, the muscle of which may be called the *tensor hamuli*, as through its agency the act of *fixing* the hooks is performed. On the *ventral* median line in *Terebella nebulosa* thick muscular transverse scale-like rugæ, mistaken by Montagu for actual scales, are developed, forming in part a fulcrum for muscular action, and in part steadying the cephalic end of the body, with a view to the pulley-like operation of the tentacles. In *Terebella conchilega* the setiferous feet are only sixteen in number, the hooks and setæ differing very slightly in model from those of the former species (fig. 25). The feet effect a similarly ventral situation, and the scale-like rugæ under the thorax present a corresponding character, only that in *Terebella conchilega* the ventral median line is painted *red* by a *band* of cutaneous pigment, which is commonly mistaken by cursory observers for a large blood-vessel. In two other and much smaller species, which the author has recently added to those generally known, the setiferous feet in one are thirteen in number, and in the other eight; in the latter they stand on prominent peduncles, and differ strikingly from those of the other species. The hooks vary only in the number of the teeth and in size (fig. 26).

The tube of the *Terebellæ*, according to the author's observation, is perforated, not cæcal, at its inferior termination. The fæculence rejected by the animal is thus made to escape from the tube, by the force of a current of the external water which is admitted into the tube, between the tube and the body of the worm, and driven out through the posterior aperture of the tube by the sudden retreating and *swelling* of the animal in its tube. It is accordingly found that in the *Terebellæ* there exists no provision, such as that which will after-

wards be explained in the *Amphitritæ*, for directing and impelling *upwards* along the tube the rejectamenta. It is desirable to remark, at this place, that in the *Terebellæ* the *number of the setiferous feet* consitutes by far the best, most constant, and most easily determined character for the establishment of the boundaries of species. Between some of the species constituted by Montagu no difference exists but that of age; the same individual at two periods of its growth is frequently referred to two distinct species. Having no fixed and constant mark of species, his definitions are vague, and quite incapable of verification. The tentacles undergo numerous variations with age, so likewise do the branchiæ; these organs are therefore valueless for classification.

The genus *Amphitrita* is also tubicolous, and generally fixed; some species, as *A. auricoma*, are distinguished however for the power of carrying their tubes about from place to place; and though tubicolous, are not therefore sedentary. In one species, *A. alveolata*, the branchiæ appear as dorsal appendages of the annuli of the anterior $\frac{3}{4}$ths of the body; in another these organs occur at two pectiniform vascular processes on either side of the neck. In a third and most beautiful species, which I have recently established under the name of *Sabina*, the branchiæ assimilate themselves in structure and situation to those of the Serpulidans. In this genus, in addition to the hooks and setæ, the feet are provided with tactile papillæ or cirri. The hooks are disposed on elevated ridges extending round the body from the bases of the feet. *First*, in *A. alveolata*, a group of flexible tentacles is gathered round the occiput, which discharge the office of sensation and prehension. On the three *first* post-occipital rings, branchiæ, cutting instruments, and hooks are developed; each hook-bearing ridge supports at *either* end a brush of acutely cutting double-edged setæ (fig. 27, *a*). These cutting tools are limited to the three first feet; they are fitted in the most perfect manner for the uses of "dressing" the materials wherewith the architecture of the tube is raised. By them rough hewn stones are polished, rugged surfaces worn down, and angry projections from the interior of the tube smoothed off. At one extremity these ridges are elongated into branchial processes; all the feet below these are furnished with setæ, which are formed on a totally different plan of structure, and which are evidently intended for a distinct office. Each seta consists of a straight flattened shaft, terminating in an extremely fine point, from either side of which minute sharp teeth point towards the free end of the seta. These setæ, from their construction, are obviously designed for pushing; that is, they constitute the agents by which the worm advances towards the mouth of its tube. Below, and at the base of each setiferous appendage, the three first excepted, a minute papilla is observed, which throughout the anterior $\frac{4}{5}$ths of the body preserves its rudimentary proportions; near the tail however these papillæ augment rapidly in size, and assume the peculiar characters of club-shaped processes, perforated at the distal end by orifices leading into their hollow axes. In these axial channels lies a bunch of singularly formed setæ, capable of protrusion to an immense distance beyond the club-ends of the fleshy processes; each of these setæ enlarges at its extremity into an oval sponge-body (fig. 27, *b*), from the base of which, in one direction, there proceeds backwards (recurved) an acute seta, and from the end, another needle-like process directed towards the root, projects on the other side. Nothing in nature or art is comparable in perfection of mechanism to these exquisite organs.

The work of scraping, scouring, planing, mopping and sponging, œconomic duties for the discharge of which art has never yet produced a *single* capable instrument, is performed by these marvellous implements alternately, successively or simultaneously with equal facility and completeness. They

preserve the inferior end or bottom of their tube-house in a constant state of tenantable purity and cleanliness, for the tube inhabited by the Amphitrite is cæcal. Another provision, of a no less ingenious description, against fæculent and noxious accumulation, is remarked in the organization of the tail. At a given point the processes and branchiæ abruptly terminate; from this point, the true tail, under the form of a cylindrical, contracted and coiled portion, extends to some further distance, and then turns upwards parallel with the body of the worm, in order with the greater mechanical advantage to project in the direction of the upper orifice of the tube the fæcal refuse. This sagacious contrivance has not eluded the discriminating eye of Cuvier.

In *A. auricoma* (fig. 28) the papillæ and cirri of the feet are entirely absent; the hooks, however, similarly disposed on transverse eminences, are stronger and larger, and the setæ are serrated only on one side. The tail-like appendage to the inferior extremity of the body, in all respects but one, is formed on the model of that of the former species. One labium of the terminal orifice is here extended into a flap-like process, which by a sudden act of muscular contraction, imparts a smart blow to the fæculent mass as it escapes from the intestine, and thus effectively conveys it to the upper outlet of the tube. This terminal extreme of the alimentary canal is richly provided with large and vigorous cilia. In *Sabina Poppæa* (Williams) the anal orifice is fringed with fleshy processes, which, clothed with vibratile cilia, fulfil offices which in the former species devolved on a specially formed tail. In all cases the office of the hooks is the same.

It is here in alliance with the Amphitrite that the author would locate the little rock-boring *Leucodore ciliatus*. Its occipital tentacles are only two in number—long, muscular and mobile; they are subservient to prehension. The thoracic region of the body is definitively marked from the abdominal, and is terminated by a foot much larger than any of the rest. The rows of hooks (fig. 29, *a*) are placed dorsally; each hook is double-toothed and supported on a long stem. The branchiæ are dorsal like those of *Amphitrite alveolata*. The feet are biramous, carrying a double bunch of setæ (fig. 29, *b*). These latter occur under three varieties of form; some are awl-like for piercing; some are pincer-like for grasping; others are plain-edged for scraping. Nothing in the structure of this little worm equals '*the tail*' in beauty and singularity. The lower extremity of the tube inhabited by it is cæcal and smooth, and not drawn out, as in other cases, into a *fine* conical cell. The tail is organized *peculiarly* and with express reference to this formation of the bottom of the cell. It is expanded with geometrical exactitude into a *hollow cone*, the anus occupying its receding apex. This remarkable and most beautiful apparatus acts on the principle of the *sucker*. Its sides are composed of a membranous muscle. When it is being applied to its point of attachment, the worm lets down its weight upon the part, in order to press out the water with which the bottom of the tube may be filled. The tail is then suddenly drawn up, a movement by which the apex of the cone is raised from the surface of contact. The pressure of the water with which the tube is filled is now rendered operative, and the little worm amid the raging billows is securely anchored to its cell. It is impossible to discover in this wondrous vital mechanism a single particular in which the principles of *hydrostatic pressure* are not minutely obeyed.

In the organization of the feet of the familiar genus *Arenicola*, there is little to call for remark. Formed to move readily through loose sand, pedal appendages are scarcely required. The brushes of bright iridescent setæ (fig. 30), which arise on either side out of the twenty anterior rings of the body, constitute the sole motor elements of the appendages. The thir-

teen last of these setæ, though beautified by the branchial tufts, are identical in structure and action with the seven anterior. The setæ consist of a long rigid flattened shaft, supporting on either side long, closely-adjusted and slender secondary setæ, after the pattern of a *pen*. They are exactly *penniform*. Such a figure fits these organs most admirably for the practical work which they are required to perform. Moving through a loose, yielding, pulverulent soil, a smooth-edged seta would oppose too *little* resistance in penetrating such a substance to enable the worm to make any forward movement. Supplied, however, with secondary setæ, which expand and separate from each other as the resistance of soil operates from the point towards the root, each foot, although planted only into sand, becomes a firm fulcrum on which the worm elongates its body and carries forward its snout in its boring operations with considerable muscular power.

A worm has lately fallen under the author's observation for the reception of which he has ventured to constitute a new species under the name of *Clymenoida arenicoida*. The anterior part of the body in all essential characters is closely similar to that of the *Arenicola*. It is to this region of the body that the setiferous feet are limited; they amount to about seventeen in number; the setæ are organized after the type of those of *Arenicola*; the snout and proboscis are also analogous: there are no external branchiæ. The posterior four-fifths of the body is two-thirds embraced by strong muscular raised rings, which support three lines of hooks (fig. 31), distinguished from all those hitherto described in the *Tubicola*, in being sustained on a long stalk, the whole forming the figure of S. These instruments are well calculated to gain for the active and boring cephalic end of the body a firm basis of movement, by securely anchoring the posterior portion to the walls of the factitious tube in which the animal is generally found to be lodged.

In these worms there are no specialized tactile organs under the form of papillæ or cirri.

In the kindred genera, however, of *Euphrosyne*, *Hipponoë*, *Pleione*, *Chlœia*, while the feet are furnished with denser and larger brushes of setæ, cirri more or less developed are found always to exist. Of these genera few illustrative species are found on the English shores. The feet are organized more for moving readily through water than a solid soil.

Several elegant representative species of the genus *Eunice* frequent the British shores. They are organized to move in underground tunnels. In structure the feet present an adaptation to the wants of such a mode of life. In the largest species of *Eunice*, as *E. antennata*, below the branchiæ, which are most dorsally placed of all the parts of the feet, a tapering fleshy process is observed, the office of which is evidently to guard the root of the branchia; it is tactile. Next to this element, on the ventral side, is situated a broad fan-shaped cirrus, fitted well for the work of rowing through water or liquid mud. This lamellated cirrus is perforated irregularly by canals, into which the fluid of the peritoneal cavity freely enters; it is also protected by two bunches of bristles, which are arranged on a *vertical* plane. At the extreme end of each seta is remarked a joint-like break, at which the junction occurs between the *end* (sabre-shaped) of the seta and its shaft (fig. 32). The union between these two parts of the seta is not, however, an articulation. A true articulation happens nowhere in the appendages of the Annelida. These quasi-articulated setæ act on a definite mechanical principle; the extreme portion is first firmly planted on the surrounding substance, on it then as a *point d'appui* the shaft revolves, and the body of the worm is moved forwards or backwards, according to the direction of muscular action. The setæ in *E. gigantea*, of which no example has yet been found by the author on our

coasts, are armed with an articulated seta, which is bi-edged, and sometimes serrated. In this species the foliaceous cirri are wanting. The subgenera *Lycidice*, *Aglaura* and *Œnone*, present, in the construction of the mechanical constituents of the feet, examples of exquisite contrivance.

The solid elements entering into the composition of the feet of *Lycidice Ninetta*, occur under two varieties: the first is limited to the superior foot, the second to the inferior; the superior foot consisting of the branchia, a protrusile foot from the end of which the setæ proceed, and in the axis of which they run freely under muscular agency. These setæ are constructed for rowing (fig. 33); they include two forms of oars; the first having a flattened blade-like shape, and that in which the expanded extremity is abruptly cut across spade-like (fig. 33, *a*). These oars are capable, while in action, of being turned upon their own axes, in other words, of being "feathered." The terminal edge of the spade-like variety is minutely serrated, adapting it for scraping when required. The setæ of the inferior foot are quite differently formed. They are composed of a long strong stem expanded at its extremity, to which is attached a second piece bifid at its remote end, and designed for hooking or fixing or anchoring the body, according to the medium in which the animal may be moving. A ligament-like membrane ties on one side this articulated piece to the shaft. It is not impossible that this sort of joint may be the faint foreshadowing of the true articulations observed in the members of Insects and Crustacea. The anatomist must not, however, misinterpret this statement. In the Annelids, as already stated, there is no true articulated member; the pieces of the hard parts or setæ are *never* united together by *joints* properly so called. The setæ, being in all cases composed of a whalebone-like substance, remarkable for its elasticity and tenacity, are readily modelled into innumerable forms without the necessity of actual joints. In all cases the *connected* portion is *continuous* in substance with the supporting shaft. In some cases the weak point of union is strengthened by a ligamentous membrane (*never* muscular), which is really only a portion of the setæ thinned off into a membranous form. To such a mechanism the word 'articulation,' in its correct anatomical sense, cannot apply.

Below the setiferous foot in *Lycidice* is observed two foliaceous blunt cirri, useful in swimming and feeling. The author has discovered two or three smaller species of *Lycidice*, in which the feet differ from the former in the construction of the soft parts, retaining in the setæ the same type of formation, while the hooks present slight variations.

The worm described by Savigny under the name of *Aglaura fulgida*, of which no British specimen is known on our coast, exhibits the same type as that of *Lycidice* in the organization of the appendages.

Œnone maculata is a graceful and active worm. Its feet are formed at once with a view to ready and vigorous locomotion through loose soil or through water. Each foot is composed of two flat fleshy appendages, of which one is dedicated to respiration, and the other to tactile and mechanical purposes. The setæ, which are placed intermediately, supported on a protrusile base, consist of long shafts, the ends of which are curved upwards and club-shaped, the under surface being deeply notched into hooks which recurve (fig. 34). An elastic membrane is also at this end of each seta, the object of which seems to be that of wiping and cleansing the hooks by passing over their plane surface. This worm is capable of creeping over a hard surface at a very rapid pace. Each opposite pair of feet constitute for its supporting annular segment an independent mechanism for progression; the posterior part of the body is not therefore dragged or drawn

forwards by the anterior. Each ring throughout the body has its own legs, which move with perfect independence. Remarkably long and gracefully slender, then, as the body of this worm may be, *every part* advances or recedes at one and the same time, and locomotion is active and vigorous. Under such a complicated repetition of oars, hooks, paddles and fins, a final result, unerringly harmonious, is obtained, which man's ingenious handiwork would attempt in vain to imitate.

The *Nereids* constitute the most common and most obtrusive family of sea-side Annelids. The majority of the species inhabit galleries, detectable under every stone between tide-marks, along which they crawl like subterranean beasts of prey. They are by no means inviting to the eye, either by their colour or conformation. They are carnivorous in habits, and perpetually on the watch for prey. In nearly all species the feet are constructed with express reference to progression on solid surfaces. Among the *Nereids*, in the classification of species, it is very important in determining the characters of the feet, that those compared in different individuals should be selected as nearly as possible from the *same* region of the body. The cephalic feet in one should be compared with those in another species from the same division of the body; those from mid-body with others from mid-body, and those near the tail with others from the same part. If this be not done, and done with exact and minute accuracy, it will be found quite impossible to arrive at a clear knowledge of constant and invariable anatomical characters for the definition and limitation of species. In all *Nereids* the feet are biramous, but coalescent at the base. Every foot, in every species, consists of a superior and an inferior cirrus, three papillæ, generally described as branchial, and two tubercles armed with compound bristles. The superior tubercles are always situated between the dorsal and second papillæ, and the inferior tubercle between this and the ventral papillæ. In *Nereis margaritacea* the setæ are jointed, the articulated piece being serrulated, and seeming calculated only for walking. The setæ of the superior feet always, in the *Nereids*, differ in structure from those of the inferior feet. In *N. margaritacea* the extreme portion is sabre-shaped and fine-edged (fig. 35). In *N. renalis* the same portion presents a finely toothed edge (fig. 36). In the superior foot the setæ are strong, and the connected piece is short, strong, curved, and always serrated; while those of the inferior are more slender, and longer, the connected piece being needle-shaped and prolonged. These worms are endowed with no mechanical means for the construction of their galleries, unless they be those of the jaws and proboscis. The feet are mainly constituted for walking; the setæ, if destined for such work at all, can only scrape and polish the interior of the gallery *when made*. Viewed by the light of mechanical principles, nothing can be so obvious as the *reason* why the setæ in these as in nearly all other Annelida are *jointed*. If they consisted of rigid, unbending levers, it is manifest that they would prove most awkward additions to the sides of the animals; if fixed too deeply in the surrounding soil, they would not act at all as levers; if too superficially, the worm would be compressed in its tube at the moment when the setæ of the opposite feet would meet in a straight line. These difficulties are effectually and skilfully obviated by the introduction of a joint or a *point of motion* on each seta. This is one instance among many, which the eye of the mechanician would detect in the organization of the Annelida, in which nature takes adroit advantage of mechanical principles in the attainment of her ends.

The *Phyllodocidæ* are by common consent the most ornamental worms among the *Nereidæ* ("Virgines pulcherrimæ inter Nereides," Fab.). They

owe their beauty of form to a series of compressed foliaceous lamellæ, which attain in some species a considerable size, and which in all elegantly garnish the sides of the body. The office of these appendages has already been described as that of 'breathing;' they are well fitted, however, to aid in progression through water. Following the motion of the feet, and capable of being partially altered from a horizontal to a perpendicular position, they operate as a brush of oars, and must prove especially useful when the worm glides from a solid surface, and finds itself unsustained in the water. Hence the species are quick and lively, and swim with great mechanical facility. "Currit egregie; natare etiam valet lamellis suis retroversis oblique sursum erectis," says old Fabricius of them in his 'Fauna Grœnlandica.' The occiput and snout are armed and ornamented by cylindrical tentacles, which are the modified homologa of the lamellæ of the feet. Observing the habits of these worms, it becomes at once obvious that these appendages are acute organs of touch.

In all the *Phyllodoce* the feet are uniramous. There is only one setiferous process, and this is capable of elongation and retraction as usual. The brush of bristles is always situated between the dorsal lamella and the blunt ventral cirrus. The setæ are jointed in all species (see figs. 37 and 38). The joint is apparently constructed on the ball-and-socket principle. The base of the extreme piece is enlarged into a small knob, while the end of the shaft is hollowed into a cavity, into which the former accurately fits. These two parts are really tied together by means of a ligamentous membrane extending from the margins of the acetabulum round and over the ball, to embrace the stem; and yet it is not a true articulation; its action is due to elasticity, not to any muscular voluntary agency. In *P. viridis*, one admirably adapted for walking on solid surfaces, the extreme articulated portion, pointed to the acuteness of a needle, is first firmly fixed on the unhinged surface: the other now lifts the body of the animal forwards, moving upon this as a fulcral pivot. In an undescribed species, the stem of the seta at its distal end and on the under side, is "roughened" with strong teeth, for *pushing* purposes. Other minor varieties in the *structure* of the bristles occur in other species. In *P. lamelligera*, the most attractive of all, a second foliaceous lamella is superadded to the respiratory one, and the setiferous process is ventralmost in situation. The tail in the *Phyllodoce*, without exception, is provided with two flattened styles, which exceed in size by three or four times the lateral appendages, and which act on the principles of the caudal fin of the fish in sculling and helming. It is a remarkable fact, proving their true homology, that the styles in the Annelids, wherever they exist, are formed on the model of the lateral cirri. When these last are blunt and clavate, as in a new species which the author has lately established, the former are blunt and clavate accordingly; when acute and flattened, the latter are so also. The styles, however, are always considerably larger in dimensions than the lateral cirri. This correspondence of plan does not, indeed, obtain between the *tentacles* and the lateral appendages. The former are nearly round and tapering, while the latter may be flat.

An exception to this rule occurs in the *Syllidæ*, in which the two orders of appendages present the same character. In this interesting genus the appendages are distinguished for their extreme length and slenderness. The feet are uniramous or undivided. The superior cirrus it is, which by its unusual length and tasteful figure and easy movements, procures for these little Annelids their charm for the eye. Elongate and submoniliform throughout their entire length in *S. armillaris*, *S. maculosa*, and *Psamathe*, these branchial cirri are beaded only through the distal half of their length.

The question of how far they are capable of fulfilling a respiratory function was formerly considered. That they are of great use in locomotion and sensation admits of no doubt. The inferior cirrus in *every* species is short and unjointed. Between these cirri is placed the setiferous process. No single anatomical character is calculated to *suggest* so much with reference to the habits and manners of the Annelidæ as that derived from the structure of the setæ. Moreover, *these* characters are subject to no variation. They are in the Annelids as fixed in their constancy as the teeth are in the higher animals; they form a magic key which unlocks the hidden secrets of the œconomy and organization of these worms. In *S. armillaris*, moving over the hard surfaces of stones and shells, the setæ are furnished only with a fine shape-edged penknife-like articulated piece, well adapted to fit itself into cracks and crevices, while the extremity of the supporting shaft is pointed sharply, with an obvious view to *catch* the surface against which it is applied during progression. Faithful to the inviolable law of "appropriate means to intended ends," it may be remarked that in kindred species, differing in scarcely any other respect than that of its habitat from the former, ingenious nature, by a trifling modification in the figure of the setæ, enables *S. prolifera* to creep with ease and steadiness over the smooth and slippery surfaces of the glutinous Algæ. This object it accomplishes in the most artistic manner, merely by curving downwards the extreme end of the articulated portion of the seta. This is done twice; so that each piece is furnished with two minute hooks on the inferior side, by which, when planted into the soft vegetable tissue, the worm is enabled to secure itself 'in place' with strength and certainty. The author has recently discovered that in two species of *Myrianidæ* which affect similar situations in Algæ, the setæ exhibit a structure which is designed to secure the same object, which are no less marvellously adapted to the exigences of the case than the feet of the house-fly or those of the Polar Bear.

In *Psamathe fusca* there prevails an arrangement of the setæ which is the exact reverse of the formation just described in the former species. In this Annelid, which also lives on algæ, the setæ are constructed for pushing, and not for pulling and fixing. The articulated piece is *serrated* in the direction of its point. These teeth are well appointed for catching in the soft surface while they are being protruded from their sheath. This worm therefore accomplishes its locomotion by pushing, the feet being directed backwards. The true *Syllidæ* walk by creeping, pulling themselves forwards, the feet being first thrown in advance of their respective rings.

The genus *Nerine* or *Spio* exemplifies, in the disposition and actions of its tactile and motive appendages, the principle which Paley has matchlessly expounded, that every mechanical perfection realized in the animal organism is attained in strict conformity with the laws of physics, illustrating the subordination of the principles of one kingdom of creation to those of another. The *Nerine* move with remarkable facility through sand or shingle. They progress in water slowly and awkwardly, oscillating from side to side without making scarcely any advance. This is the necessary result of a bodily structure suited in none of its mechanical appliances for progression in such an element. In loose sand, however, "the medium" in which they are designed by nature to revel, they display the most vigorous agility. By means of their pointed snout they burrow with great skill and effect, carrying passively at the sides their long *manual* appendages. The mechanical constituents of the feet are peculiarly adapted to aid in this operation. The dorsal foot, situated below the branchia, is composed of a fan-shaped cirrus, the plane of which is vertical, that is, parallel with a line carried from the

dorsal to the ventral median line round the body. On the posterior side this cirrus is protected and strengthened by a brush of strong bristles, which are opened into a fan-like form also, fortifying thus the fleshy cirrus from one edge to the other, and rendering an injury to it almost impossible: the ventral foot is an exact repetition of the former. The setæ present a very apposite figure for aiding in progression (figs. 39 and 40). During the oar-like motion of the foot from before backwards, the setæ go before the cirrus, protecting it thus from injury. The setæ resemble the common oar in figure, differing from this instrument only in having on either side of the blade a membranous process, hooked slightly at the end towards the middle piece or shaft (fig. 39). In virtue of this beautiful formation, the resistance offered by the little oar to the surrounding element is so perfectly graduated, that it slowly passes *through* the sand, while it forms the fulcral point of motion; the longer setæ are simply blade-like (fig. 39, *a*). The foot, in being carried forward to reperform the step, revolves slightly on its axis, and thus feathers the setæ, a manœuvre by which resistance to progression is very materially diminished. In *Nerine*, the tail in all species is a broad semicircular and *horizontal fin*, the anus being situated on its dorsal side. In consequence of the vertical direction of the plane of the *lateral* fleshy appendages, on that very account well qualified for aiding in progression through loose sand, the animal is scantily and imperfectly provided with the means of supporting itself in water; under such circumstances the tail comes in as an important instrument of locomotion. These observations are applicable in every detail to the case of the larger species of *Nerine*, *N. coniocephala*. This latter species differs from the former only in the structure of the branchiæ; the other elements of the appendages are identically formed, and the tail discovers the same ingenious construction. The author has added another species of *Nerine* to those described, in which the fleshy cirri are broader and larger, and better adapted for swimming, the tail having the generic typical formation. There remains one remarkable and characteristic feature of structure, with reference to the "appendages" in these eccentric worms, to be noticed. All the species of this genus may be immediately distinguished from *all* other Annelids by the extraordinary development which occurs in the occipital tentacles. From the dorsal aspect of the first or occipital annulus, two long *tape*-like appendages arise. In *N. vulgaris* they equal in length one-third of the body; in *N. coniocephala* they are not so long, but stouter and stronger.

In the new species to which allusion has now been made, these branchial appendages extend as far as the middle point of the body, so remarkable are they in length. The branchial appendages are true prehensile organs, used almost exclusively in the search for food. On their under surface, in each species, they are *transversely* roughened with angularly raised edges, these again being armed by stiff gristly spinelets, a provision expressly introduced for *scraping*, for which description of manual labour no implement yet contrived by the cunning of man can be better adapted. From the structure of the soil, that of a shelly fragile loose sand, in which the lot of these worms is cast, the perfect adaptation of these instruments to the end to be accomplished may be readily predicted. Their history in an especial manner exemplifies the rule, that even the humblest and meanest worm finds in its appointed habitat the conditions of prosperous and felicitous existence.

Glycera, although an inhabitant of the shingly sand, has yet received a special organization. It does not tunnel the soil into permanent subterranean passages like the *Nereids*; it struggles through the sand by the battering-ram operation of its proboscis. To the extremity of this vigorous organ

four strong teeth are affixed, which perform the business of so many pickaxes, in tearing and disintegrating the soil. This worm possesses no other instrument for pioneering its way through the ground than the proboscis; though a part of the alimentary system, it has therefore been cursorily mentioned here. The antennæ, which exist in *Glycera* under the character of four minute horns, crowning prettily the apex of the conical head, are exclusively organs of touch. The feet are prominent, and supported on a long muscular uniramous base. They are separated from each other by an appreciable interval. The branchia, as already described, is dorsalmost. At the inferior base of this appendage is situated the setiferous process of the dorsal foot. The setæ are very protrusile and jointed; the articulated portion being long and extremely finely pointed and penknife-shaped. In the centre of the setæ is observed a strong rigid *spine*, which, in all the Annelids in which it exists, contributes materially to the mechanical strength of the foot (fig. 41). Below the setiferous process is found a conical cirrus of a length equaling the setæ in their retracted position. This organ can be of little service in swimming; it is exclusively tactile. The inferior foot is an exact repetition of the superior, wanting the branchial process, while the cirrus is larger and flatter than the corresponding part of the dorsal. Two strong round tapering styles are superadded to the tail, which materially assist the worm in its progress through its native soil. Actual observation of its habits can scarcely be required to convince the intelligent naturalist that *Glycera* is almost entirely incapable even of sustaining itself in water. In this element its movements are those of irregular contortions and oscillations from side to side, convulsive struggles without progress. The study of its structure suffices in proof of the inference that it was made for the exact place in nature in which it is found. If the soil is too *hard*, its struggles to move are fruitless; if too *dry*, it is paralysed; if too *wet*, the proboscis is rendered useless, and it shows immediate evidence of discomfort. Its organization fits it only for a soil of peculiar consistence and structure; and such exactly are the circumstances under which it is found. The above considerations have arisen out of those bearing on the mechanism of the appendages in this merry and beautiful little worm.

Like *Glycera*, *Nephthys* is a frequenter of the sandy shore; it selects spots, however, in which the soil is quite different in several respects from that of the native places of *Glycera*. *Nephthys* lives in *fine* sand *saturated* with water. It advances through such a medium with a swimming motion. It is admirably organized for progression in water. The cirri of its feet consist of large fan-shaped processes, the plane of which is vertical and suitably appointed for *swimming*. The setæ are composed of two distinct layers, of which one is placed anterior and the other on the posterior surface of the cirral lamina (fig. 42). The brush of setæ on both sides radiates from a common centre at the root of the foot. The posterior setæ are constructed on the exact pattern of the *flattened* fibre of *striped* muscle, ending in a fine point; they are strong and elastic. Those anterior to the cirrus are much longer than the former, and assume the shape of sharp-pointed, finely serrated, bi-edged blades. From the inferior base of the superior foot the branchia depends; from the same point of the inferior, a conical cirrus. The ventral foot in all other characters is a precise repetition of the dorsal.

Nephthys is distinguishable from all other Annelids by its remarkable tail. It is a *median* style, extending to a considerable distance backwards, like the *occipital* ornament in the head-dress of the Chinese. It is singularly flexible and mobile. Its use can scarcely be conceived, unless it be that of defence for the posterior part of the body of the worm. In swimming, how-

ever, it becomes a steering and a sculling-machine. *Nephthys* progresses in water by throwing its body into a rapidly succeeding series of the most elegant undulations, maintaining at the same time a steady position of the head, advancing prettily like a fairy-wave through the fluid.

The Annelids grouped under the Cuvierian genus of *Ariciadæ* are little known. In the systematic portion of this Report, it will be seen that the author has succeeded in multiplying this genus by the addition of several undescribed species. The body of *Aricia Cuvieri* is distinguished into two distinct portions, one of which, the cephalic or anterior, is characterized by the absence of branchiæ, the presence of a double row of setiferous processes on either of the dorsal aspects of the body, and of short conical cirri beneath each ventral foot. This segment of the body is prominently annulated, and vigorously muscular. It exceeds in diameter very much the posterior; it is the true motive apparatus of the worm. The posterior two-thirds of the body is apparently motionless and lifeless, and scarcely at all capable of voluntary motion. To this region the branchial organs are exclusively limited. The setæ of the inferior feet are of a bright mother-of-pearl appearance, strong (figs. 43, 44), short and curved; they are carved on one side in a very peculiar manner. This sculptured work can only be described as resembling scales laid transversely one over another imbricately, each scale being strengthened by a minute "corpus" on the mid-point of its free edge. This variety, it is obvious from the structure, is designed for *pushing*. The setæ of the other feet are flat, blade-like, and unserrated in their edges. The brushes of setæ in the vicinity of the head are sessile, those near the feet are pedunculate. Placed on the dorsal aspect of the body, the ventral being smooth, it is easy to understand the manner and mechanism of locomotion. The soil is preparatorily channelled by the fore-part of the body, expressly constructed for such description of work. Through the gallery thus formed the posterior and passive moiety of the worm is slowly urged along by the mechanical operation of the setiferous feet, which are *dorsally* placed for this purpose. In this memoir, for the first time, several new species of *Aricia* will be described, presenting the generic characteristic of closely approximated 'rings' at the œsophageal portion of the body. Within the limits of this portion each segmental ring is furnished with four strong setiferous feet, the posterior part of the body being intestiniform and destitute of branchiæ. In another species the posterior four-fifths of the body is provided with ridges armed with *three* rows of stalked hooks.

The appendages in the *Opheliadæ* assume a new character; they are short fleshy threads attached to either side of the body, and chiefly to the two posterior thirds. *Cirrhatulus Lamarckii* is the culminating perfection of this type of structure. In this worm, elegant only for its long, wavy, bright red and filiform appendages, the setiferous feet are thrown into abeyance. Frequenting concealed passages, under stones resting almost always on a clayey soil, the presence of these worms can only be discovered by observing in the vacuity the tangled webs of red threads which seem gifted with the power of independent voluntary motion; these are at once motive and branchial appendages. This worm seems to enjoy very little power of locomotion. It rolls and coils itself in a self-emitted slime, if withdrawn from its native habitat. It is furnished on the under surface of the body with two rows of strong curved blunt spines, as if specifically intended for walking or creeping. At some little distance on the *side* of the same segment, is observed another row of setæ, much exceeding the former in length and differing from them in structure, being only long, slightly curved and flattened hairs; they are well calculated to aid in progression by pene-

trating the adjacent soil. To the genus *Cirrhatulus*, through the author's researches, several new species have lately been added. Here the setæ assume the shape of *elastic tape*, ending in a fine point, affecting on each segment a *lateral* situation. The lateral cirri are shorter and less numerous.

In *Aphrodita aculeata*, it is not difficult to discover every locomotive appliance required to move with facility through semi-fluid sand. The feet form thirty-two pairs in number; the anterior and posterior are minute, but they gradually increase in size towards the middle of the body, where they attain their greatest development. They are of two kinds; the squamiferous and cirrigerous, both varieties being divisible into two branches—a ventral and a dorsal. The ventral branch or proper foot forms a stout rough tuberculated conoid process, armed with a stout spine protruded from the pale papillary apex, and with four or five firm bristles proceeding from under the apex, and partially surrounding the spine. The spine tapers insensibly to an obtuse point, is smooth and of a pale yellow colour: the bristles are of a rich burnished brown colour, with a round shank which grows a little thicker upwards, and is terminated with a curved cutting point, like a pruning-knife: in most of them there is a tooth-like process on the inner side beneath this point. The cirrus of the foot does not reach its apex, excepting that of the first pairs; it is fleshy, setaceous, and of a pale colour. The dorsal branch of all the feet has an upward direction, and cannot be used as an organ of progression along the *ground*; that of the *squamous* feet is armed with two bundles of bristles, arranged in a fan-shaped manner: they are comparatively *short*, curved like the italic letter *ſ*, and roughened with minute granulations on the upper half; the bristles of the other brush, placed between the dorsal one and the proper foot, are remarkable for their stoutness and length; they are of a rich dark brown colour, straight, and terminated with a lanceolate point, which is notched on each side with four reverted barbs; so that the bristle resembles the barbed arrow or spear of the South Sea Islander. The notches are not opposite, but alternate, and they are enclosed within a plain sheath, consisting of two dilated valves which shut upon them. The cirrigerous foot has a single fan-shaped brush of bristles only; the bristles are simple and curved like those of the dorsal fascicles of the squamous feet, but they are more numerous, slenderer, longer, of a paler colour, and quite smooth; they are unequal in length, some of them very fine and hair-like, and the whole brush is usually matted and soiled with extraneous matters. This worm is generally an occupant of deep water. It crawls along the muddy bottom at a few fathoms below the surface. In motion on a hard surface its feet present an extremely interesting spectacle. It gives pleasure to watch the precision with which they are unsheathed, and the regularity and order with which each foot succeeds another in the slow and snail-like march.

Polynoë are always found on the under surfaces of stones, over which they are capable of creeping with considerable freedom. Their swimming capacity is very inferior—sinking soon to the bottom to crawl along. In relation to the *Polynoë* generically it may be stated, that the feet are bifid, the superior branch being small and almost confluent with the inferior, which is greatly developed; that the superior cirri are long and the inferior short and conical; that the bristles of the superior branch are short and always slenderer than those of the inferior, subulate and smooth at the point, or like the inferior bristles, somewhat thickened and serrulate along the edge. The spines present no peculiarity. The first pair of feet are destitute of bristles, but are terminated by two long tentacular cirri, which advance on each side of the head and resemble antennæ; while on the last segment we find filiform

appendages formed by a mutation of the superior cirri, and constituting a general terminal style. The setæ are serrulated at their extremities, and formed for pushing (figs. 45 and 46).

The *Abranchiate* Annelids, although destitute of outward organs of respiration, are not all unprovided with external organs of locomotion. The familiar *Lumbricus* exemplifies this statement. The Earth-worm in its movement displays great force of muscle. Its integumentary system is a complex web of strong circular and longitudinal muscular fascicles. The whole force of this machinery is brought to bear in progression on the stiff advantageously curved spines, which are planted in form of feet, in a double row on either side, on the ventral aspect of each segmental annulus. These setæ present the form of the italic *ƒ* (fig. 47), only two of which exist in each foot. To the inserted extremity of each seta an appropriate system of muscles is attached. To the free end minute flexible hairs are added, the office of which is evidently to prevent the gathering of dirt and earth on the part. These setæ will actually penetrate a *deal* board; for if the *path* of a worm on the fine-polished surface of a deal board be examined with the microscope *four* series of minute perforations may be detected. In *Lumbricus* these setæ begin at the fourteenth annulus from the head. In the act of burrowing into a fresh surface, as when the worm, irritated by the observer, strives to return to the earth, the foremost feet are firmly planted in the ground, the head retracted, and then thrust forwards with extraordinary force. It is manifest from the mechanism of this operation, that feet placed *nearer* the head, if such were the case, would rather obstruct than aid the burrowing and thrusting power of this part. A *swollen* wave of contracted rings may be seen travelling from the tail towards the head while the worm is thus engaged, showing the intermittent and successive manner in which the "labour of contraction" falls on every segment of the body. While running through its subterranean vaults, this worm continually plunges "into fresh fields and pastures new," swallowing almost with the voracity of the *Arenicola* the very substance of the earth which gives it shelter.

The little lively *Naïdes*, though terricolous in habits like the Earth-worm, are very dissimilar in organization. Of the genus *Nais* there are several marine and terrestrial and freshwater species. In all, the mechanical elements of the feet conform to a common type of structure. A strong seta, forked at the extremity for pushing (figs. 48 and 49), accompanied by one or two plain hairs much longer than the former, composes the foot. This is only a provision for enabling the worm to run up and down its soft tube, which in *N. filiformis* is constructed in bottom-mud of freshwater pools, and in the marine species in the substance of the hardest calcareous rocks. In these latter Annelids, as will be afterwards shown, there is furnished no special boring apparatus. The genus *Clymene* is remarkable for the character of its tube. The worm, in the instance of nearly every species, constructs a tube to envelope only the middle of the body; the head and the tail projecting beyond its limits. The worm, however, can by the retraction of the two extremes of its body, conceal and protect itself within its tube. These, like all other tubicolous Annelids, are provided with special mechanical organs (hooks) for moving up and down its cell. In this genus the hooks are supported on long stalks, and placed only at long distances on the body. Each row of hooks comprehends hundreds of individual hooks, so closely packed are they and microscopically minute.

The genera *Hirudo* and *Linus* are wholly destitute of external appendages, even for mechanical purposes. The former progress on the rings immediately, the latter by the undulatory swelling and tightening of suc-

cessive portions of the body. In all Annelids the *swelling* of certain portions of body in progression is accomplished by aid of the *fluids* of the interior. This is driven to a given point of the containing cavity, and then momentarily imprisoned there by the contraction of the *circular* integumentary muscles in front of it and behind it. Hereat, for a moment, the body bulges. The muscles of the integument are then excited to action, and the fluid is forcibly compressed forwards or backwards, according to the direction of the muscular agency. This is a summary exposition of the *mechanical uses* of the chyl-aqueous fluids of the peritoneal cavity, of which the vital and physiological meaning was formerly studied *in extenso*.

Nearly all Annelids are struck with paralysis when this fluid is made to escape from its cavity by a puncture through the external walls. The power of voluntary motion is suspended. The body of the worm becomes passive and flaccid. The peritoneal fluid is really the fulcrum on which all muscular action is based. Without it the worm cannot direct the contraction of its muscles with efficiency and precision. But its mechanical uses are not exclusively limited to the aid afforded in progression. It prevents mutual and injurious pressure amid the internal organs, without which the course of the blood in its proper vessels is arrested. In the leech-tribe it is the fluid which is contained within the stomach that accomplishes this important object. This singular anatomical peculiarity is also observed in the *Liniadæ*. Nothing in the history of the Annelids can be conceived more wonderful than the mechanically perfect and facile manner in which *Linus longissimus*, a worm of many *yards* in length, performs the feat of locomotion, and that too over craggy and rugged rocks. Without the *fluids* of the body, its motor apparatus would be incapable of effort.

Alimentary system.—In the majority of Annelids the alimentary system constitutes a cylindrical tube, which bears a general resemblance of outline to the integumentary, this latter forming with respect to the former an exterior concentric or embracing cylinder. As formerly explained, these two cylinders are in no instance in agglutinated contact; a space intervenes, varying in capacity in different species, to designate which the term 'peritoneal' or 'splanchnic' may be used with perfect anatomical propriety. This space is occupied by a *vital* or organized fluid, charged with corpuscles, which discover under the microscope characters distinctive of species. Independently of its physiological uses, this fluid enacts *mechanical* functions indispensable to the well-being of the animal. On it, as upon a pivot, the vermicular motions of the intestinal cylinder are performed. In locomotion the shortening and lengthening of the body in many species are quite extraordinary. The alimentary canal participates in this longitudinal motion. In the small species, as the *Naïdes*, having transparent integuments, the longitudinal play of the intestine, running as it were backwards and forwards through the integumentary cylinder with great rapidity and precision, may be readily observed. This motion, more or less appreciable, occurs even in those species least gifted with the power of elongation. The septa of the segments approximate under the action of the longitudinal muscles, and the included portion of the intestine is shortened. This process, multiplied by the number of segments in the body, will give a considerable resultant of aggregate longitudinal motion.

Although as a whole forming a cylinder, in no instance does the alimentary canal present the figure of a *smooth-walled* tube. The parietes are invariably sacculated, and often superficially multiplied in the most elaborate manner. In the lumbriciform species each segment of the body has its own independent stomach. Those of contiguous segments communicate through

an opening considerably more contracted in diameter than that portion of the intestine from which it leads. Thus the intestine of the Errant Annelids especially, may be aptly compared to a line of pears, the apex of each successive pear being applied to the base of its predecessor in the series. If these '*bases*' were prolonged on each side, the stomach of the leech would result; if compressed, that of those species in which the tube is nearly straight. The membranous bridles tying the intestine to the integument are endowed with contractile muscular property, minute fascicles of muscular fibre being detectable amidst the elastic fibres which form the bulk of the structure. In nearly all Annelids the alimentary tube is provided with two distinct orifices. An exception to this rule occurs in the instance of the *Planarian* family, in which the digestive apparatus is constructed on the type of that of the *Radiata*. There exist other minor families of Annelids in which the terminal outlet of the alimentary system is not seated at the extreme end of the body, but at a point, at the side, more or less removed backwards from the head, resembling intimately the pattern on which that of the *Sipunculidæ* is formed. These varieties will be afterwards studied in detail.

The digestive apparatus of the Annelid, considered as a whole, admits of subdivision essentially only into two portions, distinct alike in structure and function. The first would comprehend the proboscis and œsophagus, the second the glandular portion of the canal. The proboscis is no other than a modification of the œsophagus. It is analogous to the latter in structure and uses. It is not always a merely prehensile instrument. Its parietes are beset in many species with glands which contribute a salivary secretion. The jaws are only evolutions of the epithelial layer. The proboscis is to the worm what the whole buccal apparatus is to the mammal. The true œsophagus is essentially a muscular tube, in some species capable of extraordinary elongation, and destined only to convey the food from the mouth to the glandular segment of the digestive canal.

On the parietes of the glandular or intestinal segment only one class of glands is distinguishable. From various considerations, it cannot be doubted that this forms the true biliary system of the Annelid. These glands, viewed collectively, constitute a layer, more or less thick, almost always brilliantly yellow, embracing, like a membrane, the whole cylinder of the intestine. A separate glandule consists only of a minute bag, communicating by a separate opening with the intestine, and filled with oil-molecules of a bright yellow colour. These glandules become, as the posterior extremity of the canal is approached, separated from each other by a more and more sensible interval, enabling the eye to resolve them into their true elementary structure. Estimated then by the evidence derived from anatomy, the zoo-chemist would recognise only two classes of secretions in the digestive processes of the Annelid; first the salivary, and secondly the biliary. It is not without strong reasons that the inquiry may be here suggested, whether a given secretion, although physiologically identical in different orders of animals, is on *that account chemically* identical. A secretion may be entitled to be called '*bile*,' and the organ secreting it may, in all cases, with strict anatomical propriety, be called the liver, and yet the secretion, in ultimate analysis, may present the most striking diversities. According to the most recent researches of Strecker, for instance, the bile of different animals is found to contain different proportions of alkaline taurocholates and glycocholates. In the bile of fishes the resinoid constituents consist almost entirely of taurocholates, with mere traces only of glycocholates. In the bile of dogs scarcely anything but taurocholate of soda is discovered; and the same remark applies

to the bile of serpents. The observations of Strecker further show, that in the case of the dog, the nature of the *food* exercises no influence on the composition of the bile. Sheep's bile contains a great preponderance of taurocholate over glycocholate of soda; while the bile of the goose, according to Marson, contains scarcely anything but taurocholic acid.

This tendency to variation occurs even in the colouring elements of the bile. The characteristic bile-pigment is present in all classes of animals; in the Carnivora and Omnivora, including Man, it is *brown* in colour—the cholepyrrhin of Berzelius; while in Birds, Fishes and Amphibia, the same bile is intensely *green* in colour—the biliverdin of the chemist. The cholepyrrhin is always combined with soda or lime; most commonly with the former. These two varieties of biliary pigments will be found in the Annelids. In most animals, the bile of which has been hitherto examined, the taurocholate of soda is the principal constituent.

In *every* kind of bile there exist invariably *two essential constituents*, namely, the resinoid and the colouring element; the resinoid constituent is the soda-salt of one of the conjugate acids (glycocholic and taurocholic), having either glycine or taurine for its adjunct. Another extraordinary fact very recently established by Bensch, and confirmed by Strecker, may here be mentioned, to illustrate the observation that the *same function* may be discharged in different animals by a secretion which exhibits as many special diversities in composition as the organ by which it is formed varies morphologically. This fact is, that the bile of salt-water fishes consists almost entirely of potash-salts, while that of the herbivorous mammalia consists almost entirely of soda-salts, the very reverse of that which the chemist would have anticipated. Thus, then, in terms in common use in physiology, implying an essential unity of idea, particulars, essentially diverse, are utterly lost. In the invertebrate animals fat-cells constitute the chief morphological elements of the bile. There can be no doubt that between fat and bile, in the lower invertebrata especially, there obtains an intimate relationship. In the biliary glandules of the Annelida, Crustacea and Echinodermata, all that is *visible* consists only of oil-cells. Whatever be the real office discharged by these oleaginous principles, observation, chemical and microscopic, proves that they exist also in the higher animals. The proportion of fatty matter which (for instance, in man) is contained in the blood of the portal vein, is to that in the blood of the hepatic vein as 3·225 is to 1·885. It is supposed by Schmidt, that the oily matter brought to the biliary organ by the blood, resolves itself into sugar and water on the one hand, and into cholic acid and water on the other; the two constituents of cholic acid, glycerine and oleic acid, with certain proportions of oxygen, being equivalent to sugar and cholic acid. It may be at present affirmed as most probable, that the essential agency of the ultimate hepatic cells results in the production out of the blood of sugar and cholic acid, the former being eliminated by the hepatic veins, while the latter remains in the secretion, and may be regarded as bearing to the bile the same essential relation as that which exists between the urea and the urine. It must now be clear that the *action* of the bile on the contents of the alimentary tube must vary with the differences of chemical composition exhibited by this secretion. This must also be the case with reference to other organic secretions. The true gastric juice of the Annelid, however, or wherever secreted, may, for example, differ in many striking respects from that of man, and yet it may enact a part in the process of digestion essentially correspondent to that of which the human *stomach* (not the *mouth*) is the scene. There remains, however, another general proposition with reference to the chemistry of the fluids in the inferior animals which should be enounced with precision

to the comparative physiologist. The processes of preparation which the food is required to undergo in its transit from the mouth to the blood may not, and observation proves that it cannot be, divisible into the salivary, gastric, biliary and pancreatic stages, in the humble invertebrate organism as in the higher orders of vertebrated animals. The function of one secretion is in reality merged into, and confounded with that of another, and that in a manner which zoo-chemistry cannot yet explain.

In the higher animals all proximate organic principles, such as albumen, fibrine, caseine and gelatine, from whatever source derived, must in the preparatory processes, be first reduced to one common principle. Accordingly, actual observation has repeatedly proved that the organic bases of chyme and chyle consist of a *soluble* variety or phase of albumen. But in the lower animal, if this object is accomplished at all in the *digestive system*, it may be realized by the agency of some other products than phosphoric, hydrochloric or lactic acid and pepsin. In the higher animal the food first undergoes the influence of the saliva, an *alkaline fluid*; then *that* of the gastric juice, an *acid* fluid; and lastly, that of the biliary and pancreatic secretions, which are alkaline again. In the Zoophytes and Medusæ, the digestive and the blood-making processes are conducted in one and the same system of channels. How striking the contrast when estimated by the standard of what occurs in man! The parietes of these channels may in some cases be organized such as to be capable of furnishing a secretion fitted to accomplish the required changes in the vital and chemical composition of the contained fluid. But observation, in many others, places beyond doubt the fact of the absence of any such special organization in these parietes. In a memoir recently submitted to the Royal Society, the author has recorded a large mass of carefully collected evidence to prove that in invertebrated animals, the circulating or nutrient fluids are charged in great profusion with highly organized freely floating corpuscles; and that upon these moving-cells, and not upon any parietal system of glands, the function devolves of *elaborating* the nutrient fluids—of raising them from a lower to a higher grade of vitality.

The parietes of the cavities of the body and polypidom in Zoophytes exhibit no glandular formations. The corresponding parts in the Medusæ are little less specialized in structure. And this is also the case with the Echinodermata. In the Annelida, as already observed, the anterior half of the alimentary canal is furnished with an order of glands, obviously distinguishable from that prevailing over the posterior moiety. The Crustacea present a still further specialization of the glandular systems engaged in the elementary functions. Now, if in these several cases the digestive agency consist essentially of a process by which heteromorphous principles are reduced to one common principle, this object must be accomplished with a facility proportionate to the simplicity of the animal's structure and its degradation in the zoological scale: the chemistry of the humblest being becomes thus more wonderful, because more vigorous, than that of the highest animal. This reasoning must be necessarily conjectural until facts whereon to rest it are collected, to prove in what and how many respects the ultimate product of the digestive chemistry, the finished blood, differs in different animals. In the memoir quoted, the attempt has been made to demonstrate that in Zoophytes, Medusæ, Echinodermata, and the Annelida, sea-water is admitted *through* the digestive organs *directly* into the midst of the nutritive fluids; that the latter possess therefore a power of *assimilating*, vitalizing, this extraneous substance with a facility quite unknown in the higher animal.

It has never yet occurred to the physiologist to consider that a "simplicity" in the architecture of the *solids* of the animal body must involve a

correlative "simplicity" in the composition of the *fluids*. If the solids are reduced in their standard of organization, it follows that the fluids are required to be less elaborately prepared, in order to supply these solids with the materials of increase and renewal. If the solids of the Zoophyte or Medusa were complexly structured like those of the human body, the *fluids* of the Zoophyte, in obedience to the law of correlation now expounded, would present the same highly-wrought composition as those of the human body. The position then may be defined as involving a physiological law, that the processes of nutrition are simple in proportion as the animal is low in rank in the zoological scale; in other words, the fluids and solids are less and less removed from the standard of lifeless, inorganic matter, as the animal nears more and more the primordial link in the zoological chain.

These general observations will tend to remove the mystery of the absence in inferior organisms of systems of solid parts on which, in the higher, the most important functions devolve. They will also explain why it is that the digestive and circulating systems are fused into and confounded in one common order of channels; that special organs answering to the renal, of the vertebrated animal, do not exist. It is probable, from the very chemical nature of the inferiorly organized fluids of the lower grades in the invertebrate series, that there may exist in these fluids *no* urea to be removed; a renal apparatus would therefore prove superfluous and unnecessary. A separate order of gastric glands, supplying an acid fluid, may not exist in the Annelida, because that description of change which such a product is fitted to impress on the food, may not be required in order to its conversion into *their* blood*.

This subject deserves the deepest study of the physiologist. It is obviously pregnant of valuable results. The real question is, whether the same *organ*, homologously, in the animal series produces the same secretion *chemically*, capable of doing the same work and *no other*; for if, for example, the bile of the Annelid does the work, not only of bile, but also of gastric juice, then it follows, that, although the gland producing this fluid in the Annelid may be homologous with the liver of the higher animals, the secretion furnished by that gland is not the correlate of that afforded by the liver of the higher animals. Within the province of human physiological anatomy, it may indeed be argued, that although it may be proved by dissection that the group of salivary glands constitute truly one homogeneous apparatus, the parts of which bear by their texture a perfect analogy to each other, yet that *physiological* analysis and chemical experiments, on the contrary, by pointing out the diversity of the secreted fluids, and by causing the observer to notice the nervous force which regulates the secretions, teach us that each gland presides over one special act, and that, although the *structure* may be the same, the functions are performed under the agency of distinct and independent influences. It cannot, for instance, at present be disputed, that although the different kinds of saliva are poured into the mouth simultaneously, their use remains nevertheless distinct; and experience proves that the principal function of the parotid gland is to secrete a fluid which is to favour mastication, that of the sub-maxillary gland for gustation, and of the sub-lingual gland and buccal follicles for deglutition. It is only by the assistance of these physiological data that the modifications which the salivary organs undergo in the different classes of vertebrated animals can be studied and understood according to their true meaning. The characters of salivary glands are not to be deduced from their anatomical structure, their volume

* M. Bernard has recently, I find, read a paper before the Academy of Sciences of Paris, on the very points to which attention is drawn in the text.

or form, but from the nature of the functions to which they are subservient. It would therefore prove a physiological error, such as has been committed by J. F. Meckel, to look for parotid and sub-maxillary glands in birds, as those organs cannot exist; since the two corresponding functions, mastication and gustation, are generally wanting in this class of animals. It is thus clear that the use of all the salivary glands which are found in birds, should be looked upon as ministering to the only function which with them accompanies the ingestion of food, viz. deglutition. The thick and viscous fluid which is secreted by the glands of birds has nothing in common with the saliva of the parotid and sub-maxillary glands, and is perfectly analogous to the fluid secreted by the sub-lingual gland and buccal follicles of the Mammalia. The parotid is found in its greatest degree of development in such of the Mammalia as habitually chew dry and hard substances, whilst it becomes atrophied in those which live in water and feed upon moist food, though the salivary glands preserve their normal development with reference to the functions with which they are connected.

The preceding principles, drawn from considerations resting on the evidence of general physiology, will, it is hoped, prove of service in elucidating some of the difficult questions which will arise in the attempt to resolve the true meaning of the gland structures engaged in the alimentary system of the Annelida.

This class of animals, like all others, is distinguishable into those families which subsist on animal food, and into those which are phytophagous; in addition to which a smaller group may be recognised, whose food is the fluid medium in which they live, extracting from it when swallowed all that it may contain of matter suitable to their wants. The researches of modern naturalists with reference to the Mollusca, have shown that all the species of the same genus do not always inhabit the same kind of situation; for in many instances some are found on land, some on fresh water, and others in salt. These researches would throw little light on the habitats of the Annelida, since of them it may be stated at once that more than four-fifths of the whole class are inhabitants of the sea and the sea-shore.

The genus *Nais* is represented on land and freshwater by one species, the genus *Lumbricus*, by the familiar Earth-worm; while the genera *Hirudo*, *Hæmopis*, *Nephelis*, *Clepsina*, *Gordius* and *Planaria* are almost entirely land and freshwater in their habitats. With these exceptions it may be stated of the Annelida as a class, that it is exclusively marine. The marine Annelida are again subdivisible into the carnivorous and herbivorous groups; and these again into minor groups, according to the *varieties* of these two descriptions of food for which they exhibit an instinctive preference. Of the phytophagous species, many affect particular families of *Algæ*, near high-water mark; others those restricted to the ebb-line of the tide. The carnivorous species, as regards their mode of obtaining food, exhibit still more numerous varieties. These may always be distinguished by the conformation of the proboscis and of the alimentary canal. In few cases is it possible to infer the nature of the food of any given worm, merely by the inspection of the contents of the intestinal canal; it is more practicable to predicate the habits of an Annelid by the general structure of its digestive system in which the proboscis, when present, is included.

"The disposition of the alimentary canal," says Cuvier, "determines, in a manner perfectly absolute, the kind of food by which the animal is nourished; but if the animal did not possess, in its senses and organs of motion, the means of distinguishing the kinds of aliment suited to its nature, it is obvious it could not exist."—Cuvier, *Comp. Anat.* vol. i. p. 55. Trans. It will be

necessary therefore to resort to the general principles of the science of Comparative Anatomy, while elucidating the uses of these divisions of the digestive system in the Annelida which dissection discloses. The *external* organs (tentacles) appended to the head, have already been shown to be used by some species in the prehension of food. In others they subserve only the purposes of touch and general protection to the head.

The proboscis, though used also for the seizure of the food, bears not to the tentacles the remotest anatomical analogy. It is now proposed to enter at length upon the consideration of the conformation, anatomical structure and physiological meaning of the numerous varieties traceable in the organs devoted to the processes of digestion and assimilation in this class of animals.

The genera *Serpulæ*, *Sabellæ* and *Amphitritæ*, are distinguished by the fact, that they subsist on fluid food; if not absolutely so, on those minute particles of organic matter which perchance may float on the surrounding water. This water is directed in a perpetual stream towards the mouth, by means of the vibratile cilia with which in part for this purpose the branchiæ are provided. The current thus dashed against the mouth is swallowed, and the suspended particles of food arrested in the digestive organs, while the water, which was used only as a mechanical vehicle for the conveyance of the food into the interior of the body, is rapidly carried along the intestinal canal, and ejected through the extreme outlet of the body, situated at the bottom of the tube, in streams sustained in rapid motion by the ceaseless vibration of definitely disposed cilia. This water current, traversing in the manner indicated the whole interior length of the body, constitutes 'a fact' of great consequence in the œconomy of these tubicolous Annelids. It is through its agency that the feculent refuse is projected from the bottom to the upper orifice of the tube, and that the habitation of the worm is maintained in a state of never-varying cleanliness and purity. The rectum or *tail* extremity of the intestine in *these* genera is lined *internally*, and to some distance inwards from the anus, with large and vigorous cilia, which at this situation reinforce the current descending along the intestine and drive it outwards with great force.

In the *Serpulæ*, the pharynx and œsophagus extend from the oral orifice to the termination of what may be called the thoracic segment of the body; whereat is situated a crop-like dilatation of the canal. The pharynx and œsophagus are beset on their internal surface with numerous minute follicles, which contribute a secretion having some digestive property. The walls of this segment are delicate and membranous. At the 'crop,' however, the parietes present increased density, having become more strongly muscular. The uses of this portion of the canal are manifestly those of crushing minute fragments of stones, sand-particles, &c. which may be swallowed; that this description is swallowed by the *Serpulæ*, may be proved conclusively by the observation of the sandy and earthy contents of the intestine posterior to the crop. Like the corresponding structure in graminivorous birds, it is in these worms a crushing and grinding engine. It is curious, however, to remark, that it does not exist in some few species of *Sabellæ*, so nearly akin in organization to the *Serpulæ*; it is present in *Amphitrita alveolata* (Plate XI. fig. 50 *a*), absent in *Sabella chloremа*, absent also in *S. vesiculosa*. The presence of this dilatation of the canal is ordinarily indicated externally by a *bulge* of the body. From the annulus, coinciding in situation with the crop, the true intestine begins (fig. 50 *b*); this portion of the alimentary tract in nearly all Annelids, is characterized by a bright yellow-coloured, streaked by a rich network of strikingly red blood-vessels, composing a surface of

great beauty. At this point the true biliary apparatus begins; it is the source and cause of the yellow colour. The ultimate glandular cells of the liver are disposed in minute groups, square or round, or oblong, according to the figure of the space enclosed by the ultimate capillaries of the vascular mesh. No part of the structure of the Annelid is so profusely supplied with blood as the parietes of the biliary segment of the intestine. There are here detectable in all species elaborate reticulations, while a blood-vessel can only with difficulty be observed in other parts of the body. The group of oil-cells contained in a separate involucrum, just large enough to occupy a *mesh* of this *rete mirabile*, constitute the liver in real fact. This little group of oleous molecules, floating in a semi-fluid substance of a brilliantly yellow colour, represent the real elements of the biliary organ. In no instance, in any species, is any departure from this type of structure exhibited; the liver, therefore, in these animals is diffused under the character of a bright yellow flocculent stratum, over *nearly* the whole extent of the alimentary canal. It is most developed near the mid-body, the elementary glandules becoming gradually more distinct and removed from each other in proportion as the tail is approached. In the *Serpulidæ*, *Sabellæ*, and *Amphitritæ*, the rectal portion of the intestine dilates, becomes greater in diameter, and the orifice itself is a capacious opening. It is not difficult, in this provision, to perceive the manifest indications of design; by it every obstacle to the free escape of the contents of the intestine is removed; no impediment, such as that would be if the orifice were guarded by a *sphincter* muscle, is offered to the action of the cilia, upon the efficient operation of which the well-being of the little cell-prisoner so completely depends.

The intestinal system of the *Terebellæ* (fig. 51) differs in several material respects from that of the *Serpulæ* and *Sabellæ*. The œsophagus, a strong muscular tube, in this genus is remarkably long; it is not however in the least degree protrusile. These worms are distinguished for the strength and muscularity of the lips, which are superiorly and inferiorly placed with reference to the mouth. These appendages to the mouth are well-adapted in a mechanical sense for swallowing mud, soft earth, clay, and dirty water. During their slow, awkward and tedious locomotion, the *Terebellæ* carry the mouth close to the ground, the lips being actively at work in turning up the soft soil. The posterior half (fig. 51 *a*) of the œsophageal tube is embraced by a bright yellow glandular mass, differing from the ordinary biliary layer in being composed of larger, more prominent, lobulated masses. It is quite indisputable, both from its structure and situation, that this is a true glandular structure, and that it supplies a secreted product tributary to digestion. From this structure the lesson may be drawn, that the comparative physiologist should not feel too confident in assigning a *biliary* function to any structure in the inferior animals merely because it possesses a *yellow colour*. Other glandular structures generate the yellow pigment, while instances might be multiplied in considerable number, in which *true* biliary organs are *not* distinguished by a yellow colour, but by a green, or dark brown. In the progress of our studies in the Annelidan class of Invertebrata, the varieties mentioned in the mere *colour* of the liver will soon fall under description. From its position around the posterior end of the œsophagus, the glandular organ in the *Terebellæ* supplies probably a fluid bearing some analogy to *saliva*, and yet it is far too elaborate a structure to be dedicated exclusively to a mere salivary function. Here again is an illustration of the difficulty of determining the strict meaning of an organ on the mere ground of a similarity in anatomical relations; no less fallacious is that resting on analogy of ultimate structure. These physiological difficulties are

not encountered in the anatomy of the higher and more *specialized* organisms; but in inferior forms, fusions of organs and substitutions of functions are frequent in their occurrence.

In the *Terebellæ*, the œsophagus is succeeded by a segment of the canal, distinguished by the absence of the yellow colour. It presents the characteristics of an elongated gizzard (fig. 51 *b*); the parietes of this portion are muscular and dense, and little vascular. It is generally found on examination to be devoid of contents; the alimentary substance does not stop or lodge in it. This gizzard-like portion is followed by the true biliary intestine, divided by constrictions into annular segments, equalling those of the integument in number, although not similar in character. In intimate structure this portion answers with exactness to the Annelidan type. The bile-gland consists essentially of minute lobuli of oleous molecules (fig. 51 *c*), enveloped in a common capsule, surrounded by a blood-vessel, and opening into the intestine by a common orifice. It is remarkable that in these animals there should exist such a monopoly of blood in the biliary apparatus, while so little blood-proper is observed in the body as a whole. From this circumstance it may be reasonably argued that the *bile* in these inferior forms of organization unites in itself some *other function* in the work of primary assimilation than that limitedly defined office which is discharged by the bile of the higher animal. The biliary glandular layer of the intestine becomes thinner and thinner as the posterior termination is approximated; and the contents acquire more and more the excrementitious character. The rectum, as in the *Terebellæ*, expands, and ends in a large anal outlet; the *interior* of this part of the intestine exhibiting, as in kindred genera, a rich lining of vibratile cilia.

Arenicola Piscatorum lives almost exclusively on sand. The 'coils' observed on soft sandy shores, supported always by a substratum of clay, are caused by these familiar 'lugs.' The sand is swallowed as the animal advances through the soil, traversing the whole extent of the body; and yielding up for the purposes of digestion what it happens to contain of organic matter, it is finally rejected under the form of sand-coils, remarked so commonly on the sea-shore. *Arenicola* is capable of exserting the pharyngeal membrane to some distance beyond the extremity of the head (fig. 52 *a*). When thus protruded it answers all the mechanical purposes of a proboscis, although devoid of hard parts, or jaws. The mucous surface, both of this part and of the œsophagus to some distance inwards, is thickly beset with minute glandules projecting in relief above the surface. They contribute the *first* organic fluid to the action of which the food is submitted. Deglutition is impracticable in this worm, unless the sand be almost saturated with water; dry sand cannot be swallowed, and if too wet, it is not well grasped by the proboscis.

The œsophagus (fig. 52 *b*) is a strongly muscular tube, surrounded by a frame-work of four longitudinal vessels, with detached smaller branches for the nutrition of this segment of the canal; compared, however, with the intestinal segment of the canal, the œsophagus is scantily supplied with blood. At the point of junction between the œsophagus and true intestine, and just anterior to the cardiac centre of the blood-system, may be seen two pyriform bodies (fig. 52 *c*), *hollow* in the interior, and communicating by a large opening with the channel of the œsophagus. They are sometimes found to contain a greenish yellow fluid, which tinges the surface over which it flows. The microscope entirely fails to discover in the parietes of these diverticula of the œsophagus, any evidences of glandular formation,—nothing to throw light on the mechanism of their secreting function. It may be affirmed with

certainty that they do not enact *any* part concerned in the reproductive functions. With the organs devoted to the latter uses they exhibit no sort of communication. The structure of the œsophageal parietes are coloured by no pigment. The intestine proper, however, coincides to the Annelidan law, and displays the brightest yellow colour, streaked in every direction by the plexiform blood-vessels, in the meshes of which the biliary gland-structure is lodged. A correct conception of the ultimate structure of intestinal parietes may be derived from a close examination of the figure of the circulation of *Arenicola*, formerly given (Plate III. fig. 7, *f*). At the commencement of the posterior third of the body the digestive canal of this worm loses its enteric character. The liver-enveloped tube degenerates into a smooth-walled, straightened canal, stretching under this form from this point to the tail; the traces of segmentation so general in the digestive system of the Annelida are here scarcely perceptible. Although destitute of biliary glandular tissue in its coats, the posterior straight segment of the canal is surrounded by a curious loose flocculent tissue, which both Lamarck and Cuvier have mistaken for a part of the reproductive system. Each elementary process of this tissue consists of a *single* vessel, terminating in a *cul-de-sac*, and enveloped in a layer of nucleated cells; they project to the distance of about the eighth of an inch from the exterior surface of the intestine; they are also attached to the interior surface of the integumentary cylinder, a few extending from the one to the other. Milne-Edwards defines them as "appendices secréteurs de la matière faune, excrétée par la peau" (vaisseaux biliares?). Lamarck has described them as ovaria. As already stated, they consist of a *single* vessel (*not* a *looped* vessel), around which a layer of nucleated cells clusters. If these cells produce anything, it must enter the blood-channel, which forms the axis of the process, and thence mingle with the blood. If they do *not*, the blood-vessel must be regarded merely as a collateral receptacle into which the blood may rush during the contortions of the animal, and as bearing some analogy to that system of vessels which surrounds the lungs of the cetacean mammalia. If they are glands, they are most certainly destitute of excretory ducts. If they are designed to supply a fluid tributive to digestion, it is anomalous that they lie disposed over the *hindmost* segment of the digestive canal. There is no character detectible in the structure of the cells suggestive of their true function. Neither these appendages, nor the pyriform diverticula attached to the œsophagus (Plate XI. fig. 52 *c*), can in the present state of knowledge be physiologically defined. It is not easy to explain, within the limits of the same class of animals, why the *same* secretion should proceed in different species from organs so remarkably dissimilar in structure. Between these pouches in *Arenicola*, for example, and the salivary glandules which beset the proboscis and œsophagus of nearly all other Annelids, there exists no homological affinity. Analogy therefore affords no ground whereon to rest the supposition that their secretion consists of saliva. Neither can it consist of bile, for already an extensively diffused gland is furnished for the production of this fluid. It admits of no denial that special necessities arise in some species of animals, from the nature of the food, obliging the provision of some special organ to supply peculiar wants. The physiological signification of such organs cannot be explained on "general principles." The peculiar want must first be understood, the peculiar correlate of that want may then be defined.

In *Arenicola* the cutaneous system is very profusely supplied with mucus-producing follicles. The slippery secretion by which the animal is externally covered, must very materially facilitate its progress through the sandy soil of the shore, by diminishing the friction between its sides and those of the

channel through which it is advancing. It requires little knowledge of the composition of the sand of the sea-shore, saturated twice every twenty-four hours by the tide, to understand that the food of these worms must share the properties of the animal and the vegetable kind. The inferior forms of life swarm in every minute mass of sand. The microscope detects thousands of infusoria and entomostraca, and fragments of algaceous vegetables; these organic substances constitute the food of these worms. The sand swallowed "gives bulk," distends the canal, and sustains by mechanical contact, the stimulus required for the due vermicular action of the tube.

Clymene arenicoida displays a proboscis formed precisely on the same model as that of *Arenicola*, and devoted to the same uses; as this worm, like *Arenicola*, lives on sand. The digestive system, however, is constructed very differently from that of the latter. The œsophagus is short, the biliary intestine begins near the head, and continues without any variety of structure to the tail. Neither the diverticular pouches of the œsophagus, nor the gland-like flocculent vessels noticed in *Arenicola*, are detectible in this species; so that while the food and proboscis are identical, the digestive system presents nothing in common in the two species. Another exemplification is here given of the difficulty and danger of predicating the function of an organ from the nature of its anatomical structure.

The cognate genera of *Amphinome*, *Chloe*, *Pleione*, *Euphrosyne*, and *Hipponoë*, far from common on the British coasts, in the pattern of the alimentary canal, approach more or less intimately to the dorsibranchiate type already described.

The *Euniciadæ* (Plate X. figs. 53, 54) are invariably armed with a powerfully-jawed proboscis. It is capable of protrusion to a very slight degree beyond the level of the mouth; when fully extended it does not extend to the point of the head. The jaws in all the species are very similarly formed and disposed on the proboscis. Taking *E. antennata* for type, we observe that the jaws are symmetrically bilateral, moved by strong *muscles*. The *corneous* processes on either side of the proboscis, which constitute the jaws, are seen to consist of two denticulated plates or saws, the teeth being directed inwards, of a reaping-hook like piece, blacker in colour and stronger than the former, and presenting a sharp edge; and another straight, tapering, and acutely pointed piece, which in some species is situated to the outside of the former, and in some to the inside. In such an engine the mechanician may recognise the presence of the crushing, cutting, sawing, and piercing elements artfully designed to do the multifold labour which the proboscis of these rapacious worms is required to perform. In their native haunts they prowl under stones, and closely resemble the *Nereids* in their habits, affecting similar situations. The œsophagus in this genus supports the tubular heart, and presents the characters of an elongated gizzard. The intestine is brilliantly yellow throughout the middle third of the body, and segmented by constrictions corresponding with those of the external body. The ultimate anatomy of the biliary layer corresponds with those accounts of this organ already given: it is densely vascular. Although the biliary gland commences in front by an abrupt defined line, it very gradually disappears posteriorly, nor entirely until it reaches the caudal extreme of the body. The anal orifice is situated on the *dorsal* aspect of the tail, the latter being prolonged into two long styles. It is a fact of fixed constancy in the organization of the Annelida, that the outlet of the alimentary canal is situated *dorsally* whenever it is not terminal. In the *Serpulæ*, *Amphitritæ*, *Terebellæ*, it is *terminal*, the mouth being also terminal. Whenever the anus is *dorsally* situated, the mouth is *ventrally* placed; these are fixed quantities in the organization of the Annelids.

The genera *Lycidice*, *Aglaura* and *Œnone*, are distinguished readily from *all* other Annelids by the existence of *four styles*, two on either side of the anal outlet. It is not a little to be wondered at that such exact observers as Audouin and Milne-Edwards should have overlooked this most peculiar conformation. In all other respects the portraits of these worms given by these distinguished authors in Crochard's edition of the 'Règne Animal,' are faithful and characteristic. These genera, remarkable for the beauty of the curves into which their very elongated bodies are thrown during locomotion, frequent, in search of food, all those situations in which the *Euniciadæ* are found. To the latter family they bear an intimate resemblance in the structure of the jaws of the proboscis. Like that of *Eunice*, this organ is short and armed with jaws of four separate plate-like pieces on either side (fig. 53 *a*). The edge of each element presented towards the median-line is denticulated with recurved short serrations. The two inferior portions are drawn into the shape of a reaping-hook, the base being toothed. The description now given applies more especially to *Aglaura fulgida* of Savigny.

In *Lycidice Ninetta* (fig. 54) the jaws comprise three elements, having each a peculiar conformation. The inferior jaw is a flattened club-shaped instrument adapted for *slicing*; the next displays the form of an acutely-pointed reaping-hook, while the next is bluntly serrated. These three peculiarly constructed instruments are evidently designed for three distinct mechanical purposes in the seizure and mastication of food. In another species of *Lycidice*, hitherto undescribed, the proboscis is furnished with jaws which are composed of pyramidal pieces only, and adapted exclusively for piercing. The hook-like and serrated elements are wanting. This species is found only on certain *Algæ*, and its food is probably of an exclusively vegetable nature.

The proboscis in the genus *Œnone* coincides closely in character with that of the two preceding genera. The jaws occur under the shape of curved denticulated plates. In the conformation of the alimentary canal in these genera there is nothing peculiar to be noticed. The œsophagus is long, and terminates where the biliary segment begins. At this point it is embraced by a large circular vessel, by means of which a communication is established between the ventral and dorsal moieties of the circulating system. It is strong-walled and muscular. It is destitute of glandules; these are limited to the parietes of the proboscis.

In the biliary intestine of this, as indeed of nearly all other Annelids, the *stomach* proper and intestine are confounded both in structure and in function. It is not improbable from the disproportionately extensive tract of surface over which this yellow glandular organ is distributed in the Annelida, that the product secreted by it may unite the qualities of the gastric and biliary digestive fluids. On the possibility of such fusion of functions, observations have already been adduced.

Dr. Johnston observes with reference to the proboscides of the *Nereids*, that "the pattern after which they (prickles of the proboscis) are arranged, varies in some species; but it is almost impossible to define those variations in words, and the character fails us in the nearest allied species, where only it is required. Such is also the case with the number of serratures along the falcate edge of the jaws; though the character is one not to be neglected; but from the peculiar shape of the jaw, I have sometimes found a difficulty in determining the exact number of these serratures; and in other instances have had a doubt whether one or two of them, from their obsoleteness, ought to be reckoned*." These difficulties do not accord with my experience. With a good microscope it becomes quite clear always that different species, however nearly allied, are characterized by proboscidian jaws of *distinctive*

* Annals and Magazine of Natural History, vol. iv.

conformations. This, however, is only true with reference to adult individuals, since it is easy to assign to distinct species individuals which really differ only in age, and that on the ground of an apparent difference in the form and shape of the proboscidean jaws.

The *Nereids* (figs. 55, 56, 57, 58) swallow a considerable amount of clay and sand. Observation of the habits and habitats strongly suggest, however, their carnivorous disposition. The proboscis is well-constructed, and the jaws aptly disposed, for seizing a living prey. The intestine is filled always, especially throughout the posterior half of the body, with a pulpy matter, of which sand and clay form a large proportion. These worms frequent subterranean channels constructed by themselves; and this mechanical purpose is not the least important of the uses to which their proboscides are devoted. Through these haunts they move with great rapidity. They prowl on all animals which perchance may be brought within the precincts of their territory by the mechanical force of the tidal currents.

As the British species in the genus *Nereis* amount to a considerable number, it were tedious in this place to enumerate all the specific variations from the generic type which are found to occur in the figures of the proboscidean jaws (figs. 55, 56, 57, 58). In the *definition of species*, these particulars may hereafter prove of essential service.

Assuming for type this organ as it occurs in *Nereis margaritacea* (fig. 55), it is found to be capable of extrusion to some distance beyond the line of the head; that the jaws are two in number, one on each side of the terminal orifice of the proboscis; that each jaw consists of a falcate, horny, dark process, the internal curved edge of which is irregularly *notched*: the characters of these notches become distinctive of species. In some they are uniformly round; in others they are sharp and recurved; in others these serrations point forwards. This latter is the case in more than one of the smaller species. It is important to remember that in no species of this genus do the jaws exceed 'the *pair*' in number. In addition to the jaws, properly so called, the proboscis in some species is pricked with minute corneous points at various parts of its surface, for the purposes obviously of protection from external injury. In *N. margaritacea* the œsophagus extends backwards to the level of the seventh or eighth foot; it is a straight muscular tube as usual; but it is curious to observe that the two lateral pouches communicating with the œsophagus already described in *Arenicola*, re-appear in the genus *Nereis*. They are obviously identical in structure to those of *Arenicola*, and subservient to similar purposes. At the distance of three or four feet beyond the point of these pouches the biliary intestine begins. It is strongly segmented. In the smaller species the interval of constriction equals in length the sacculated portion. The only means of distinguishing between the limits of the true 'digestive' intestine and the *colonic*, consist in the character of their respective contents; true fæcal matter never lodges in the former, it always accumulates in the latter. In those Annelida, as the *Nerine*, for example, which are remarkable for the elongation of the body, the posterior half or third of the intestinal canal is loaded with fæculent accumulations, imparting their colour to the whole body. The system of the blood-proper, as formerly indicated, is elaborately developed in the *Nereids*, and the walls of the digestive canal are embraced by a dense tissue of a closely reticulated plexus. In the *Nereids*, the integumentary structures are far more vascular than those of any other known Annelid. This circumstance suffices to account for their proverbial muscular activity. The evidences of structure and habits concur to support the view which assigns to these worms an almost exclusively carnivorous character.

The *Phyllodocidæ* unquestionably live exclusively on animal matter. They are always found near low-water mark, amongst corallines, sponges, minute Actiniæ, shelled Mollusca, and Cirrhipeds. *Phyllodoce viridis* prowls amidst the small Cirrhipeds of our rocks, and is frequently found in companionship with the *Liniadæ.* These worms may be frequently observed to thrust their heads between the valves of the shells, protruding their proboscides to suck up the juices of the defunct prey, for they seldom attack the living inhabitants. In all the species of this genus the proboscis is constructed with express reference to the operation of sucking. This instrument, in these worms quite ceaseless in its operation, is edentulous. It is gifted with no means of grasping, or cutting or piercing; circumstances from which it may be reasonably inferred that the food upon which the worms subsist must be so fluid as to admit of being *sucked* into the oral orifice seated at the extremity of the proboscis. This instrument in *Phyllodoce viridis* equals a fourth of the body in length when fully extended. The surface, which is exterior when protruded, is beset profusely with mammillary glandules raised above the plane of the surface. Under the higher powers of the microscope these glandules resolve themselves into minute Florence flask-shape involucra, filled with spherical oleous cells, which, unlike ordinary oil-molecules, are charged with brownish molecules surrounding a central nucleus. It is impossible to trace with the eye the presence of an excretory channel in the axis of the flask. It is therefore probable that the secretion furnished by these proboscidian papillæ (as at 58), considerable in quantity, evidently from their vast number, results from the successive bursting of the contained cells; those dehiscing first which are situated nearest to the attached extremity of the gland. When withdrawn into the interior of the body, the proboscis may be seen in an inverted position embraced by the œsophagus. It may be here remarked, that in every Annelid in which a proboscis exists, the process of withdrawing it into the interior of the body is as beautiful as it is perfect in a mechanical sense. The jaws, when they are present, first meet at the mid-point of the terminal orifice of the proboscis; they are then reversed, that is, their extremities are directed backwards towards the tail of the animal: they may now be seen moving backwards in the axis of the œsophagus as the act of withdrawing the proboscis proceeds. To explain the mechanism of this movement, it is required only to conceive the existence of two concentric cylinders of longitudinal muscular fibres; one on the outside of the proboscis under the papillæ, and the other on the inside beneath the mucous lining. It is now easy to perceive, that when the *exterior* cylinder retracts, its muscles *contracting*, the effect on the proboscis will be that of *everting* or protruding it; and when, conversely, the *interior* cylinder of muscular fibres diminishes its length (the muscles *contracting*), the proboscis will be furled upon itself, as it were, and drawn backwards into the interior of the body. The orifice at the extremity of the organ, whether guarded or not with jaws, is surrounded by a sphincter muscle, by which the alimentary object is firmly grasped while being carried back into the œsophagus during the inversion and retraction of the proboscis. These movements may be readily imitated by the finger of a glove. It is a curious anatomical fact, that the glandules furnishing the secretion, to the agency of which the food is *first* submitted, should be restricted to the parietes of the proboscis, since those of the œsophagus, properly so called, are generally without a trace of them. Such glandular organization points to the proboscis as the analogon of the mouth and pharynx, with their tributary glands in the higher animals. For reasons, however, already advanced, it were unsafe, on the ground of this apparent analogy, to rest the inference that

the papillary glandules of the proboscis, like their elaborate representatives in the mouth, furnished a fluid for the exclusive purpose of insalivation.

In the *Phyllodocidæ* the biliary intestine begins where the mechanical œsophagus ends. Neither a crop nor a gizzard intervenes between these two divisions. It is on this account that the inference, denying to the proboscidian glandules an exclusively salivary office, is rendered probable. These glandules in reality may supply a fluid, uniting in its chemical agency the twofold properties of the gastric and the salivary.

The segmentation of the body, exteriorly, is in these ornate worms very deeply marked. This fact determines the degree in which the intestinal canal is segmented. It is curious, however, that the œsophagus should in no case conform in the outline of its structure to that of the integuments. In no known instance is it sacculated or annulated, like the intestine. This latter division of the canal in these worms is quite moniliform in figure, the contiguous sacculi being divided by an interval of constriction equal in length to themselves. The *biliary glandules*, which in the *Phyllodocidæ* are charged with a dark green pigment, are limited in their distribution to the dilated portions of the intestine, and may be traced in diminishing numbers to the extreme tail-end of the tube. It is probable that the absence of the characteristic colour in the biliary layer of the intestine may depend in some way upon entire *absence* of all *red* pigment from the blood. Such facts as these, bearing to each other an evident though unresolved connection, suggest the conclusion that all *local* pigmentary accumulations, whether occurring in glandular organs or integumentary structures, are mere modifications of the primary pigment matter of the blood. The blood in the *Phyllodocidæ* being devoid of all colour, it is accordingly difficult to conceive the source whence the materials of colour may be drawn by the biliary organs. In confirmation of this doctrine the instance of *Phyllodoce viridis* may be mentioned. All the structures in the body in this worm are strongly tinged with a grass-green colour, and that probably because the blood is densely charged with this pigment.

The *Syllidæ* (Plate XI. fig. 59) are proboscidian worms, and no known species presents an exception to this rule,—in some they occur as minute transparent bodies on the *inside* of the orifice of the proboscis. This organ in *S. prolifera* (fig. 59) exhibits four of these little corneous formations (fig. 59 *a*); they are crenated at their distal end. In *S. armillaris* these piercing instruments are replaced by a *single cup-shaped* organ, of the mechanism of whose action it is difficult to form a correct conception. It is placed on the superior edge of the terminal orifice of the proboscis; the edges of this orifice being fringed with fleshy papillæ, which are obviously, from their situation, the seat of exaggerated tactile sensibility. In other species there is no corneous formation of any sort superadded to the proboscis. These Annelids are generally found creeping over the surface of algaceous plants. From the absence of any structure bearing the semblance of browsing organs, or mechanical additions of any description to the proboscis calculated to cut and masticate vegetable substances, taken in conjunction with the circumstances under which these worms are commonly discovered, they may be classed with confidence among the herbivorous Annelida. This conclusion is supported by the anatomical proofs derived from the character of the digestivecanal.

In the *Syllidæ* the proboscis (fig. 59 *b*) is capable of extrusion to a considerable distance beyond the mouth. Unlike that of nearly all other Annelids, it is quite *smooth* and destitute of all traces of parietal glandules. In this genus the papillary glands are transferred to the walls of the *œsophagus* (fig. 59 *c*). They may be readily seen projecting beyond the plane of the ex-

ternal surface of this part of the tube, in form of transparent vesicular tubuli filled with minute cells. To the œsophagus in *all Syllidæ* succeeds an elongated highly glandulated gizzard-like portion peculiar to and characteristic of this genus (fig. 59 *d*). The parietes of this portion are not perhaps dense and muscular enough to claim for it the character of a true gizzard. The glandules are arranged in transverse or circular rows, and communicate with the interior by means of a minute excretory tube or orifice. One type of structure prevails throughout all varieties of the secernent glandules, whether biliary or salivary, discoverable in the digestive system of the Annelida. They resolve themselves, in ultimate analysis, into membranous capsules filled with secondary cells, for the most part oleous. These cells are contained in a plasma, out of which they draw the material of their own formation and increase. They dehisce and contribute thus a perfected secretion, adapted to perform a part in the chemical and vital processes of digestion. The biliary intestine in these worms presents a deeply notched outline, approaching the moniliform (fig. 59 *e*). The segments of that part which immediately succeeds to the gizzards are very much elongated, while those nearer the tail present annulations corresponding with those of the integument. The biliary layer in these worms is not pigmented bright yellow, but *dull* yellow, having a greenish tint. There is nothing demanding notice in the formation of the *rectal intestine* in the *Syllidæ*. The outlet is situated dorsally and above a small median style. As the blood-proper is destitute of colour, there is little difficulty in explaining the absence of brilliant pigments from the solid glandular structures of the body.

The genus *Spio* or *Nerine* comprehends two well-known species, *N. vulgaris* and *N. coniocephala*; to which number the author has lately added *N. Marcella*. These Annelids are notorious for the extraordinary accumulation of fæcal matter which occurs in the posterior half of the intestinal canal, causing the whole of this moiety of the body to look closely like an inanimate string of sand and earthy substance. This character is more striking in the two last-named species than in the first. *Spio vulgaris* is an *active worm*, and the posterior half of the body does not drag like a lifeless appendage, as it does in *S. coniocephala* and *S. Marcella*. These worms are improboscidean. The head terminates in a prolonged tapering snout. The mouth is situated ventrally and a little *behind* the extreme end of the head; the lining membrane of the pharynx is capable of being only very slightly exserted. It is by the operation of the arms that food is conveyed to the mouth. The chief part of this food consists of sand, fragments of shells, &c. In consequence of the conical figure of the snout, these worms penetrate the gravelly and shelly soil in which they are found with great facility. That portion of the body which corresponds with the œsophagus, contrasts prettily by its dull white colour with the rest of the body, which is dark green. The oral two-thirds of the œsophagus is a smooth tube, unsupplied with glands (Plate X. fig. 60 *a*); the remaining portion, as far as the intestine, embraced by a flocculent layer consisting of a vast multitude of follicular glandules (*b*). They coincide in structure with those which in the carnivorous Annelids beset the proboscis. The first fifth of the true intestine is generally empty and thickly furnished with parietal biliary glands. At this part the colour is dark green. The perfect yellow does not appear in these worms. Next to this portion occurs the colonic segment of the canal, which is distinguished by its earthy contents, the dark green of the integuments becoming sensibly diminished, enabling the contents of the canal to contrast strongly with the anterior portions of the body. The segmentations of the anterior part of the intestinal canal are deeply marked, the tube being reduced at

the constricted intervals to a fine thread, through which, into the contiguous segment, a minute portion of fæcal matter periodically passes. The biliary glandules on the parietes of the intestine present a definitively linear arrangement; that is, when traced around the cylinder they form circular rows of glands.

In *Glycera alba* (Plate XI. fig. 61), the alimentary canal is remarkably moveable; it is tied to the integumentary by bridles of *muscular* fibrillæ. This most attractive and lively little worm inhabits loose moist sand, through which it progresses by frequent thrusts forwards with its proboscis. The jaws of this organ are four in number, hook-shaped (fig. 61 *a*), each presenting a secondary piece projecting from the back; the base being strong and broad. The extremity of the proboscis is smooth, while the posterior four-fifths is thickly villose with papillary glandules (fig. 61 *b*). The œsophagus exceeds the proboscis in length, enabling the latter to be packed upon the former. The intestinal segmentations commence at the œsophagus; there is no proper stomach. The functions of the stomach are merged either in those of the proboscis, or in those of the biliary intestine. In numerous examples it has already been shown that this conformation is frequent among the Annelids. From the peculiar character of those '*zones*' of the sea-shore in which this worm is ordinarily found, it is probable that it subsists on the organic material contained in the soil, of which it swallows considerable quantities.

Nephthys Hombergii is commonly discovered in fine sand, saturated with sea-water. It swims with facility. Its proboscis presents a formidable appearance. It is edentulous, the jaws being, however, replaced by fine but strong fleshy bristly processes. The digestive canal is found in general heavily laden with the sandy refuse of digestion. Its parietes are pigmented with a bright yellow colour; the œsophagus slightly exceeds in length the extended proboscis; the intestinal canal is annulated in correspondence with the integumentary. The constrictions between the segments are only slightly marked.

It may with great probability be affirmed generally of those worms which subsist by swallowing the soil in which they live, that the real food is a mixture of animal and vegetable matter, since the soil of the sea-shore abounds as much in minute fragments of algaceous vegetation as in living and dead animal matter. No part of the body of these worms is coloured by the contents of the intestine. The whole animal presents a general dirty mother-of-pearl appearance. They attain a considerable size, and exhibit in the adult state extraordinary muscular power. The œsophagus in this worm supports a very long single vessel—the cylindrical heart. It is little vascular, and quite devoid of follicular glandules; these latter are restricted to the proboscis. The œsophagus is a strongly muscular tube, in consequence of the part which it is required to perform in the protrusion and retraction of the proboscis. The proboscis, being a large bulky appendage to the œsophagus, gives to the latter, when withdrawn, an apparently greater diameter than any part of the intestine. The absence of a vascular web on the parietes of the œsophagus, excludes it from the physiological actions of digestion; it is in this worm, as in many others, a mere mechanical tube. The biliary intestine is highly vascular; it is embraced, in conformity with the dorsibranchiate type of the intestinal circulation, by four large longitudinal trunks, from which lateral vessels proceed to form a dense reticulation of capillaries. It is in the minute spaces between these ultimate vessels that the biliary glandules are lodged.

In the organization of the digestive canal of the *Ariciadæ*, there is little to

remark which does not fall under the description already presented. The intestine is of a bright yellow as far as the tail. The colour of the biliary yellow pigment of the intestinal parietes blending with the dull white of the integument, these worms appear as yellowish-white threads, twisting about with great beauty. They are distinguished, like the *Spios*, by the fact that the whole of the posterior three-fourths, or more, of the body hangs on, like a lifeless coil of sand, to the cephalic and only active and locomotive part of the body. The former is apparently dragged along by the latter in progression. Although supplied with feet and branchiæ, they seem in this region to take little part in the movements of the anterior part of the body. This incapacity for muscular movement seems to depend upon the *weight* of the earthy mass contained in the intestine. The blood being brightly red, the branchiæ form a pleasing contrast with the dark colour of the body: These worms live on sand, and are destitute of proboscis. The head is prolonged into a finely tapering snout, by means of which its march through the sand is effected with tolerable facility.

The preceding description will serve to convey a pretty exact idea of the character of the alimentary canal in the *Opheliadæ*—worms which are not uncommon on the British coasts. The author recently made several additions of species to the list of British *Ariciadæ*; they are distinguished from the old species by a shorter body, by the presence at various points of filamentary appendages, not unlike those of *Cirrhatulus*, by a far greater activity in the posterior parts of the body in progression, and by the absence of the earthy colour, and undue accumulation in the posterior moiety of the digestive canal.

Cirrhatulus Lamarckii, so abundant between tide-marks on the coast of Swansea, subsists almost entirely by swallowing clay. Its long branchial appendages are little subservient to, and less used for the prehension of food. The mouth, a small circular orifice, is ventrally situated, and some little way posterior to the tapering snout, in which the head terminates: it is well adapted for sucking in semi-solid food. The pharynx is susceptible of eversion in a slight degree. The native colours of this worm are beautifully variegated: the brilliant yellow of the intestine, which begins near the head and continues to the tail, relieved by the greenish hue of the integuments of the back, contrasts agreeably with the vermilion thread which spangles every portion of the worm. The alimentary canal, from one end to the other, is closely united, at short intervals, by means of minute septal bridles, to the integuments; the peritoneal fluid, on that account, is very limited in quantity. The course of the intestine describes a zigzag from one extreme to the other. The œsophagus is short, and the proboscis wanting. The biliary glandular layer of the intestine is thick and flocculent, and densely supplied with blood. This worm is capable of throwing out from the general cutaneous surface a considerable amount of viscid adhesive secretion, which enables the worm to roll itself in an impenetrable coat of mail. The mechanical act of applying the surrounding substances to the body is accomplished by the thready appendages. Nothing can be more exquisite than the perfect and yet rapid manner in which these microscopic strings perform this work of protection. In its natural state *Cirrhatulus* does not inhabit channels. It is commonly found in soft semi-fluid clay, stretched under stones near the ebb-mark of the tide.

The family of *Aphroditaceæ* are uniformly proboscidean. Many members are found in deep water, rendering it difficult to assign their exact habitation. The *Polynoë* are inhabitants of the shores, and affect protected situations, such as the inferior surface of slates and stones, over the

surfaces of which they crawl in search of food. The œsophageal apparatus, with its appended proboscis, is always powerfully muscular. Some anatomists have assigned the name of the "gizzard" to the true œsophagus in *Aphrodita aculeata*. Whatever outward resemblance this part may present to a gizzard, it possesses none of the structural characters of this latter organ. Its parietes are powerfully muscular and dense, because they are the engine by which the proboscis is thrust out and drawn in. The extended proboscis of *A. aculeata* is a savage-looking instrument; in size it is proportionate to that of the animal, and is *edentulous*. The oral orifice of this proboscis is encircled by a short and thick-set fringe of compound penicillate filaments, divided into sets by a fissure on each side; each filament has a short stalk, with a tuft of numerous forked papillæ on its summit; exterior to the orifice of the proboscis there are four fleshy tubercles placed at the angles. As the external surface of the proboscis and that of the œsophagus are devoid of all glandular structure, the *internal* lining membrane of both these portions of the digestive tube is *glandularly* organized, that is, the membrane is *villose* and highly vascular. It is important to remember this fact, for it denotes an anatomical feature which belongs to all the *Aphroditaceæ*, embraced in the four leading genera *Aphrodita*, *Polynoë*, *Pholoë*, and *Sigalion*. Plate X. fig. 62 illustrates the outline anatomy of the alimentary system of *Polynoë squamata*. It exhibits a striking approach in plan to that of *Aphrodita aculeata* (*c*, *c*, digestive cæca). From its position in the alimentary tube, it is manifest that this villose œsophageal membrane furnishes a fluid which is concerned in the process of digestion; it does not extend in any species beyond the limits of the œsophagus. The true stomach is quite dissimilarly organized. The proper occasion has now arrived for explaining the real physiological meaning of the complicated cæcal appendages, so familiar to the comparative anatomist, by which the interior capacity of the digestive cavity is multiplied in the *Aphroditaceæ*.

These appendages, in their *mechanical* arrangement, realized two important objects:—

1st. They effect the purpose of lodging and detaining a considerable quantity of a dark-greenish *chymous* fluid.

2nd. They are so disposed with reference to the large exterior current of water which rushes under the elytra or scales, as to bring their *chymous* contents as closely as possible into contact with this aërating medium.

They perform, therefore, two supreme functions, namely, that of respiration and digestion. Perhaps this latter process, in this particular instance, should be designated as that of *sanguification*, since the fluid contained in these cæca is evidently the blood in its first stage of preparation; it is the fluid which, when absorbed into the circulating system, becomes the true blood. It is to the *Aphroditaceæ* what the chylo-aqueous contents of the peritoneal cavity is to all the other Annelids. This cavity in the Aphrodites, like that of the Echinoderms, is occupied by a fluid, which in appearance and composition closely approaches sea-water. It can scarcely be doubted that this cavity, thus filled, becomes in these eccentric worms a reservoir wherein oxygen *accumulates*, and that from this store, in part at least, the fluid contained in the digestive cæca draws its supply of the aërating element. In the *Aphroditaceæ*, the blood-proper is colourless, and the blood-system of vessels is very inferiorly developed. The median tube of the stomach, which is straight and unsegmented, and from either side of which the cæca proceed, is *always* found to be filled with a semi-solid fæculent matter, which is quite unlike that contained in the cæca. These two portions of the contents of the digestive system are kept apart by a sphincteric structure encircling the openings leading from the straight stomach into the

lateral cæcal appendages, an arrangement, by which, in the most perfect manner, everything *but* the digested chyme is excluded from the cæca, exemplifying in humble life, the principle on which the "pylorus" acts in the higher animals. The above description will serve to convey a precise conception of the conformation of the alimentary system in the other genera of Aphrodites, namely, in *Polynoë* (Plate X. fig. 62), *Pholoë*, and *Sigalion.* In these smaller Aphrodites, the true stomach is limited to the *posterior* $\frac{2}{3}$rds of the body; the œsophageal portion, with its embraced proboscis, engaging the anterior. It is necessary to observe, that, as in *Sigalion Boa*, the peritoneal fluid, external to, and enveloping the digestive appendages, assumes a highly organized and blood-like character, having express branchial organs provided for its own exposure to the aërating element. This, however, is only a modification, not a violation, of the principle already enounced. It should be here stated, that in the *Aphroditaceæ*, the true biliary apparatus is distributed in form of a dark green glandular layer over the parietes of the digestive cæca, and that it is exclusively limited to these situations.

In the genera *Lumbricus* and *Nais* (fig. 63), the digestive canal is a simple segmented tube, brightly coloured yellow by the glandular biliary layer forming one of its coats.

In relation to the mechanism of alimentation in the suctorial Annelids, which comprise the subgenera *Hæmocharis*, *Albione*, *Branchellion*, *Clepsina*, and *Malacobdella*, the following principle may be definitively enunciated,—that there exists in all species an *inverse proportion*, both as regards quantity and quality, between the fluid contained in the peritoneal cavity and that of the digestive cæca. It is accordingly found, that when the stomach is reduced to the simplicity of a straight tube, unsupplied with lateral cæca, the chamber of the peritoneum is spacious, and replete with a highly organized fluid; that, on the contrary, when the stomach is multiplied and complicated by the addition of lateral appendages, filled with a chymous fluid, the peritoneal space becomes reduced in capacity, and almost entirely deprived of contents. The fluid, thus balanced, is not changed physiologically when transferred from the peritoneal chamber into the interior of the digestive cæca, or *vice versâ*. Of the genus *Hirudo*, the following are subgenera, of which the digestive system is sacculated:—the common Leech, in which the sacculi are largest; *Hæmocharis*, in which the hindmost pair only are highly developed, the rest in front being small; and *Aulastoma nigrescens*, in which the whole of the anterior portion of the tube is perfectly straight, having only two long cæca at the posterior extremity, on either side of the rectum.

Albione muricata presents a digestive tube perfectly devoid of all lateral sacculations; this is also the case in the genus *Branchellion*, and that of *Malacobdella*. These Annelids are all suctorial. In some species a sucker exists at both extremities, in others at the posterior only.

Nemertinidæ.—In the 'Règne Animal' the genus *Nemertes* is thus characterized:—"C'est un ver d'une mollesse et d'un allongement extrêmes, lisse, grêle, aplati, terminé à une extrémité par une pointe mousse percée d'un trou; évasé et largement ouvert à l'extrémité opposée par où il se fixe. Son intestin traverse toute la longueur du corps. Un autre canal, probablement relatif à la génération, serpente le long de ses parois, et finit à un tubercule du bord de l'ouverture large. MM. d'Orbigny et de Blainville, qui ont vu cet animal vivant, assurent que c'est l'ouverture large qui est la bouche."

"La seule espèce connue (*Nemertes Borlasii*, Cuv.) a plus de quatre pieds de long. Elle se tient enfoncée dans le sable, et attaque, dit-on, les anomies qu'elle suce dans leur coquille. Je dois ce ver singulier, dont Borlase (Corn-

wall) seul fait mention à M. Dumeril, qui l'a trouvé près de Brest. M. Oken en fait son genre *Borlasia*, M. Sowerby l'avait nommé *Lineus*."

In the preceding definition Cuvier commits himself to several important points of structure, the incorrectness of which, it will be subsequently shown, may now be proved by easy and direct demonstration. It is first stated that the body in these worms terminates in a blunt point perforated by an anal orifice. This is an unquestionable error. The posterior extremity of the body in all the species of this genus is imperforate. It is next affirmed that the intestine traverses the whole length of the body, and that "*another* canal, probably concerned in generation, winds along the sides, and terminates by a tubercle *on the side*, by a large orifice." The constituent elements of structure have thus been accurately recognised by Cuvier, but very erroneously interpreted. It will be hereafter demonstrated that "the second canal," terminating at the side, is concerned in digestion, not in generation. It is a compound of œsophagus and proboscis. The figures by M. Quatrefages of *Nemertes Borlasii* represent this worm as possessing several longitudinal fissural oral orifices adapted for sucking. Nor does it appear that this sagacious naturalist had become at all acquainted with the existence in this remarkable Annelid of a *proboscis*. His conception, therefore, of the mechanism by which it obtains food must have been remote from the truth, since the oral end of the alimentary system is not many-fissured, but composed only of a single longitudinal slit underneath the conical rostrum: with such an orifice it is manifest that the process of suction would be impracticable. In the beautiful illustrations of the anatomy of *Nemertes Camilla*, published from the inedited researches of M. Quatrefages in Crochard's edition of the 'Règne Animal,' this author describes the *jaws*, which are situated at the extremity of the proboscis when protruded (an extraordinary organ in these worms), as being contained in a pouch of the digestive *cavity*, "poches à stylets en voie de formation." The dissections of this worm by M. Quatrefages are, notwithstanding this instance of a misinterpretation of structural characters, accurately defined, and, as far as they have extended, confirmed by those of the author. It is, however, not a little surprising, that the *real* organic characteristic of these worms should have eluded the eye of an ingenious observer, who had attained to a point bordering closely on a true solution of the problem, viz. the real mechanism of the proboscis and œsophagus. And in relation to the function of that large glandular mass which constitutes so considerable a proportion of the whole bulk of the worm, M. Quatrefages shares the erroneous views already propounded by Cuvier, both describing it as a reproductive (ovarian) organ.

In the year 1844 Prof. Œrsted of Copenhagen published an important contribution to the anatomy and systematic description of the *Nemertini* *. The diagnostic descriptions of this observer prove beyond question that he also missed the right clue to the secret of the true organization of these worms; he describes the buccal fissures as designed to admit water into contact with the heart for the purposes of respiration. He describes the anal orifice as having a terminal situation. He states that the proboscis is "*nullum exsertile*," and, like Cuvier and Quatrefages, he falls into the error of characterising the 'glandular organ,' which occupies nearly the whole length of the body, as the reproductive apparatus †. In fact, the differences between the

* Entwurf einer systematischen Eintheilung und speciellen Beschreibung der Plattwürmer, Kopenhagen, 1844, p. 76.

† By M. Œrsted the *Nemertini* are regarded as a suborder of *Vermes Apodes*, and are characterized as follows :—" Corpus lineare teretiusculum rarius depressum, multo longius quam latius, indistincte annulatum, mucosum, ciliis vibrantibus obsitum ; musculi distincti,

results of the inquiries of Œrsted and those obtained through the author's investigation are so striking and irreconcileable, that one or other of them must be egregiously false. Rathke has published descriptions of what he announces as new species of *Nemertinidæ.* As our desire is in this place only to refer to such points of structure as relate to the alimentary system, it is necessary merely to report, with reference to the descriptions of M. Rathke, that some of the diagnostic characters are thus given. "At the anterior margin of the body a small opening was found which Rathke did not regard as a mouth, which lies further down on the abdominal side, and is represented by a large longitudinal cleft. On the right and left of the anterior end of the body is a boat-shaped, superficial, longitudinal furrow, to which a strong bundle of nerve passes from the red ganglion of the brain. . . . . . The intestine, running out straight at the posterior end of the body, contained a whitish slimy fluid, from which circumstance this author conjectures that the *worm* sucks its nourishment from other white-blooded animals, as a great number of small, thin, cuticular sacs, which were attached in a single row, behind each other, on the inner side of the body of this worm, contained in some individuals distinct eggs, and in others sperm-cells. Under the dorsum runs a very long snow-white and spiral canal, which is very muscular, and lies bulged out like a proboscis at the opening first mentioned. Rathke confesses that he *could not succeed in determining its use.*"

By Ehrenberg it is held that the part described by the preceding authors as an alimentary canal is really an egg-passage, while he regards the white spiral organ as the alimentary canal. Enough has been cited historically, to convey to the comparative anatomist some conception of the chaos and darkness which brood over the problem of the organization of this genus of Annelids. The observations of Mr. H. Goodsir* on this subject must not be omitted. By this author a description of two species of *Nemertinidæ* is published, one under the name of *Serpentaria,* the other under that of *Nemertes.* With reference to the former species, Mr. Goodsir observes that the anterior extremity of the body is pointed, with the proboscidean orifice obscure and imperfectly developed; the male generative apertures on each side, and the cloaca on the abdominal surface immediately behind. Mr. Goodsir further states, that as the animal has no true proboscis, the proboscidean orifice is very small or imperfectly formed, which renders it difficult to be seen. On each side of the rostrum there is to be seen a longitudinal narrow slit, generally closed, and communicating with the male generative system. Immediately behind these, and on the abdominal surface, is another larger orifice, which the animal has the power of opening and shutting at pleasure. When open it is of an ovoid shape. The edges are serrated. This leads to a large longitudinal cavity which runs through the whole length of the body, but for a considerable extent anteriorly is continuous and very much dilated; in the remainder of its extent it is more confined and interrupted by the ovaries

non vero nervi (?). Oculi 2, 4, 6, 8, 10. Multi vel nulli. Organa respiratoria specialia nulla, vel fissuræ respiratoriæ laterales in capite aquæ ad cordum parietes aditum conciliantes. Circulatio completa et corda duo. Tubus cibarius simplex cum oris apertura infera (rarius terminali) et ano terminali. Os nullum exsertile. Sexus duo, in utroque organum copulationis stimulandæ. Testiculi et ovaria cava ne minimum quidem forma inter se discrepantia tantum modo contento (ovulis aut spermatozois) complura in utroque latere uniuscujusque segmenti." It will be found that this diagnosis corresponds in no essential point with the statement given in the text of the anatomy of *Nemertinidæ*; and, moreover, the inaccuracies into which Œrsted has fallen exemplify the importance of resting all 'diagnoses' on carefully instituted dissections. Anatomy alone should be the basis of all correct specific descriptions.

* Annals and Magazine of Nat. Hist., June 1845.

which lie on each side of it. All that portion of the body in which the common cavity is continuous and dilated consists of one annulus, but the succeeding or terminal is composed of a great many, each about the eighth of an inch in length.

Each of these separated annuli contains all the elements of the perfect or original animal, viz. a male and female generative apparatus, the cavity common to the generative, digestive and respiratory functions. *Serpentaria* therefore is a composite animal, each perfect individual consisting of numerous and apparently still unformed or imperfectly formed individuals.

With respect to *Nemertes*, Mr. Goodsir makes the following observations. Anterior extremity of the body rounded, somewhat quadrilobate, with the proboscidean orifice in the centre. Male generative apertures on each side. Cloaca or abdominal surface immediately behind. The anterior extremity is slightly quadrilobate, and in the centre there is a small foramen, through which a long, narrow, extensile, trumpet-shaped proboscis can be protruded at the will of the animal. On each side of these are two narrow longitudinal slits similar to those in *Serpentaria*; these, as already mentioned, are apertures to the male generative apparatus, which consists of two long, narrow cellular tubes, running down each side of the body. The cloaca on the abdominal surface of the body is small and rounded, and opens into an oblong cavity similar to that of *Serpentaria*. With reference to an alleged orifice at the *posterior* termination of the body, Mr. Goodsir states that the opening was so large that it appeared in process of filling up after the last separation, admitting thus the fact of the existence of a *terminal anal orifice*. This excellent observer proceeds to remark, "that the leading features in the structure of both these species are similar. The large common cavity in both species is common to the respiratory, digestive and generative systems. The water in which the animal lives is *transmitted through this cavity*, and thus acts as a means of respiration. In *Serpentaria* it acts I would say almost altogether as an organ of digestion, and for this purpose its construction is slightly different from that of *Nemertes*, in which animal the structure approaches more to that of the true *Planaria*, in so far as it is endowed with an extensile trumpet-proboscis, which is continuous with a large puckered-up tube running along the upper and central part of the common cavity, and which, contrary to the supposition of Rathke and other naturalists, is, according to the opinion already expressed by Ehrenberg, the intestinal canal. It is tied down at intervals by strong fibrous or muscular bands (mesentery), which, when unwound, allows the intestine to escape from its attachments. The ovaries which run down on each side of the body have no means of throwing off the ova except into the common cavity. It appears to me therefore that Ehrenberg is correct in supposing that cavity to be an egg-passage, and in *Serpentaria* this is more fully shown than in *Nemertes*."

From the preceding quotations it is obvious that Mr. Goodsir's ideas with reference to the anatomy of the *Nemertinidæ* are by no means clearly defined; he first states that there exists a terminal anal orifice, while at the same time he describes the presence of a cloaca on the abdominal surface not far from the head; he affirms that the water is admitted *directly* into the *great* cavity of the body, contending at the same time that in this cavity the threefold office of respiration, digestion and generation is discharged. It will be hereafter shown that the views of Mr. Goodsir, in relation to the *plan of structure* on which these eccentric Annelids are organized, differ most widely from those to which the author of this Report has been conducted by his own investigations, and which are now published for the first time.

In the recently published researches of M. Emile Blanchard* on the anatomy of the Entozoa, physiological opinions are expressed which lend support to the errors already exposed.

This naturalist, to whom science is so much indebted, characterized the voluminous spongy organ which constitutes by far the greatest part of the bulk of each segment of *Tænia Solium* as the true *ovary*, entering into minute details to prove the existence in each ring of an oviduct and vulva, and a superadded sperm-producing apparatus, demonstrating thus the independence of each segmental division, as regards at least the reproductive system. M. Blanchard recognises in the minute, lateral, smooth-sided and *un*sacculated tubular threads, running *straightly* in parallelism with each border of the body, what he calls the "gastric canals," communicating with each other by means of commissural transverse branches. A system of true blood-vessels coinciding in distribution with the former is also described by this anatomist.

Now, if the views of M. Emile Blanchard be *true* with reference to the organization of the *cestoid Entozoa*, those now to be propounded in relation to the anatomy of the *Nemertinidæ* must be *untrue*. Both cannot be admitted into the category of truth; they are irreconcileably opposed. Though at variance with the fashionable doctrines of the schools, it may be enounced as an absolute law, that in the œconomy of *all* inferior organisms the alimentary exceeds the reproductive system in size and importance. The gastric and intestinal organs form in all instances a considerable part of the bulk of the body. The dissections of M. Blanchard have reduced those of *Tænia* to dimensions of utter insignificance. His descriptions are sanctioned by no analogy. It is not difficult to demonstrate that the zoological affinities of the *cestoid Entozoa* suggest conclusions with regard to their organization which the isolated and undirected results of dissections cannot disprove. When however the mind of the anatomist is first awakened to a conception of the typical principle of structure which prevails throughout the *Nemertinidæ*, *Planariæ*, *Trematoda*, on the ground of their zoological consecutiveness in the scale, he will cease to doubt that the same principle of structure, though opposed to his anatomical observations, obtains amongst the *cestoid Entozoa*. It is really, however, in practical anatomy easy to establish a unity of plan in the organization of this series. The direct continuity of the Entozoan and Annelidan chains is rendered unquestionable by investigations thus directed. Although the laborious researches of M. Emile Blanchard render it probable that no oral orifice† exists in *Tænia*, the digestive character of

* Annales des Sciences Naturelles, 1848, 1849.

† At the present stage of my investigations, I by no means desire to commit myself to this doctrine. On the faith of the trustworthiness of M. Blanchard as an observer, I concede for the present, *argumenti gratia*, the probable truth of his results. But on this admission it is not difficult to show that *Tænia* is clearly *within* the boundaries of the plan of structure on which the *Nemertinidæ* (under which designation I would rank the freshwater *Gordiusidæ*, the *Planariadæ*, the genera *Borlasia*, *Lineus* and *Serpentaria* (Goodsir)) are organized. I have hitherto enjoyed only an imperfect opportunity of dissecting the Tape-worm, my observations having been confined to a few segments from the mid-body; but I have seen enough of its structure to convince me that it falls within the type prevalent throughout the *Liniadæ*, *Borlasiæ* and *Planariæ*; that the great central organ, which hitherto all anatomists, including M. Blanchard, have concurred in regarding as the ovarian apparatus, *is in truth a great digestive cæcum*. *If it be true*, as affirmed by Prof. Owen, and after him by M. Blanchard, that neither an oral nor an anal orifice exists in *Tænia*, then the alimentary fluid upon which the parasite subsists must be drawn by suction through the suctorial discs, directly into the interior of the digestive cæcum; and as these suctorial discs are *not* perforated, but covered by a porous membrane, the food is *filtered* as it is being drawn into the body. This arrangement, however, by no means requires that any other than a *digestive* function should be assigned to the spongy organ commonly known as the *ovarium*; for in *Borlasia*, *Lineus*

the so-called ovarium is rendered not the less probable. It will afterwards become apparent that two distinct lines of inquiry converge upon the inference that this "ovarium" of authors is a true digestive cæcum on a large scale; that it is filled by a chylous fluid, charged with organized corpuscles; that its parietes are organized with especial view to supply a secretion by which the fluid contents are *assimilated*; and that the whole force of analogical inquiry supports the view which assigns to other structures exterior to, and independent of this organ, the functions of reproduction. It is proposed at this place to enter into the details of the demonstrations which the author has to offer with reference to the anatomy of the genera *Borlasia, Lineus* and *Gordius*. The grounds will then become intelligible on which he entertains the belief that the principles of structures developed by these researches, when extended to the instances of the cestoid Entozoa, will prove no less exact.

The whole exterior of the body in these worms is one continued scene of ciliary vibration. This extraordinary fact it is essential to remember, since it will be found to bear corroboratively on the views afterwards to be explained, as to the uses of structures hitherto held as enigmatical*. At a point a little posterior to the extreme end of the rostrum, and corresponding with what Œrsted has designated *fissuræ respiratoriæ laterales*, the cilia assume an augmented size, appearing in this situation as though supplied to guard fissural openings leading into cavities. These apparent openings are really only depressions, spaces left between the cervical muscles, in order to make room for the heart, which is situated on each side immediately underneath, to expand. The red colour of these two spots on either cheek is due to the blood in the heart, which (Plate XI. fig. 64 *a, a*) is a bilocular organ. The blood colour of these spots has led nearly all observers to the mistake of supposing that the office of respiration is circumscribed to these limited fissures. The microscope, which resolves the part into its component elements, furnishes a direct disproof to this view. In structures devoted to respiration, the blood is uniformly divided and subdivided into the minutest streams. In this part this fundamental law is violated, for here the blood is accumulated into one large cardiac chamber. In these Annelids the proboscidean orifice is not terminally but ventrally situated. It is slightly behind and on the abdominal surface of the conical snout which forms the cephalic termination of the body. In itself this opening is a simple longitudinal slit, adapted for no mechanical purpose. Its sides are smooth, and armed with no mechanical instruments. It is merely an opening through which, in *Borlasia, Lineus* and *Gordius*, a powerful and an extremely long proboscis is protruded (fig. 64 B). The extremity of this organ is armed with several styleted jaws (fig. 64 *c*), which, from their construction, seem designed only to fix the suctorial end, by *perforating* the alimentary object. When the proboscis is withdrawn into the interior of the body, fitting admirably into a

and *Gordius*, the anatomy of which my dissections, I trust, have reduced to clear demonstration, the 'alimentary organ,' the great digestive cæcum, which both in general and ultimate structure is the exact counterpart of what is called in *Tænia* "*the ovary*," has been proved beyond dispute to have *no direct external communication*. Its contents, therefore, which the microscope demonstrates to consist of an organized corpusculated fluid, of a milky character (the correlate of that which in other Entozoa and Annelida occupies the *peritoneal* chamber, i. e. *exterior* to the alimentary organ), cannot be excrementitious; it is chylous. It is the pabulum which in part supplies the materials out of which the blood-proper is formed, and by which, in part probably, the work of solid organization is accomplished.

* I have not yet succeeded in actually *proving* the existence of cilia on the integuments of *Gordius*; from the resemblance of its internal structure, however, to that of the *Liniadæ*, of which the cutaneous surface is richly ciliated, it is scarcely rash to believe that in it also these motive organules will be found to exist.

short œsophagus, these sharp instruments are packed and folded upon themselves. M. Quatrefages, ignorant of the protrusibility of these parts, wrongly conceived that this was the permanent and immoveable position of these parts, and described the chambers in which the jaws were lodged as "*poches à stylets.*" The appearance of cavities or pouches is, however, altogether delusive, and depends upon the closing round the jaws of the sides of the proboscis. This organ in *Lineus longissimus* (Sowerby) is positively several feet in length, and constitutes a formidable instrument of offence*.

It is remarkable that the very existence of this proboscis has escaped the observation of the many excellent observers by whom from time to time and under different names it has been accurately described. This organ is provided with a thick stratum of papillose glands (Pl. XI. fig. 64 *d*), by which doubtless a secretion is furnished important to the digestive process. This glandular salivary product is poured into the channel of the proboscis : thence it finds its way, mingling with the fluid food, into the œsophagus (*e*), wherein it sojourns for a short period, and thence *transudes*, by exosmose, *through the parietes* and reaches the cavity of the great alimentary organ (*f*), where it assumes by slow assimilation a higher organic standard, becoming probably fitted to nourish the solids of the body, and to replenish the contents of the true blood-vessels. It will be seen that there is no direct *open* communication between the œsophageal tube (*e*) and the great alimentary cæcum (*f, f*), *nor between the cavity of the latter and the exterior.* The contents of this great cavity must, therefore, in great part at least, be recrementitious, not excrementitious.

The œsophageal intestine terminates (fig. 64 *g*) in a distinct papillose outlet, which is situated at a short distance posterior to the cephalic end ; when the proboscis is withdrawn into the interior of the body, the œsophagus lies in the cavity of the great alimentary cæcum, being traceable back to some distance in the direction of the tail. While in this position, this tube may be readily, as it always has been, mistaken for a true intestine; followed more minutely, however, it may readily be observed to return upon itself and terminate in the lateral outlet already indicated. In the mere mechanical disposition of these parts an intimate analogy may be remarked between the *Nemertinidæ* and the *Sipunculidæ*, in which the alimentary canal coils upon itself and ends in an outlet situated ventrally, about the anterior third of the body. In this case, however, there is no other alimentary organ, in which respect the *Sipunculidæ* differ most fundamentally from the *Nemertinidæ*.

The great spongy mass which in the genera *Borlasia*, *Lineus* and *Gordius*, constitutes so considerable a portion of the whole bulk of the body, commences anteriorly, immediately behind the hearts (fig. 64 *a, a*), under the character of a *cæcal end* (*h*). Although the œsophagus enters (*appears* to perforate) into the contained cavity of this organ at this situation, yet the interior of the latter is not laid open, for its parietes are reflected over and embrace those of the œsophagus. Nor is it possible to discover at any part of the course of this tube any direct opening of any sort leading from it into the cavity of the *digestive cæcum*. It is, notwithstanding, from the relative connexion of these parts, impossible to doubt that the food passes from the œsophagus, after a short detention therein, for the purpose of insalivation, into the interior of the digestive cæcum. In the absence of all proofs of a direct opening between these two cavities, the passage of the food can only be accomplished by transudation through the parietes of the œsophagus.

* Several specimens of this extraordinary worm have recently been found on the shores of the Bristol Channel, one by Mr. Lewis Dillwyn, one by Mr. Moggridge, and several by myself.

Having arrived in the chamber of this great cæcum, it will of course follow on the same ground, that the refuse matter can only escape by the same mechanism, for no direct outlet to this cavity can anywhere be discovered. It is therefore a perfectly closed sac, filled with a milky fluid. But it must not be overlooked that its interior cavity is considerably multiplied by the superaddition of *diverticula* (fig. 64 *i*, *i*) to the sides. The parietes of these last parts are more glandular, granular and darker than those of the ventral or dorsal aspect of the tube. This granular character has been invariably misconstrued by every observer into an evidence of the *ovarian* signification of these parts. The microscope places the inaccuracy of this view beyond dispute by demonstrating that these ova (*sic*) consist only of oil-globules.

This organ is tied at definite intervals, by means of minute bridles, to the integument, according to the manner in which, in nearly all Annelida, the intestine is connected with the cylinder of the integument. At its posterior, caudal termination it has been proved, by repeated observations, that *there exists no orifice*; of this fact there is no doubt. It is then proved by direct demonstration that there is neither an inlet nor an outlet to this remarkable organ, and it is hoped that evidence has been accumulated to superfluity, to establish its digestive character. But through another line of inquiry these proofs receive additional force. At short distances, along the whole line of the body of these worms on either side, membranous sacculi may be defined with readiness in the interval between the alimentary tube and that of the integument. It is on *these organs* undoubtedly that the office of reproduction devolves. If this be *not* their true function, no other can be assigned to them; and if this *be* their real meaning, it follows that no other than that of digestion remains for that organ, which the author has ventured to designate as the *great alimentary cæcum**.

The key to the real organization of this unfamiliar group of Annelids having thus been forged by the demonstration of the structure of a few typical and illustrative species, material assistance is afforded for unlocking the difficult anatomy of all the allied genera. Taking for groundwork the *plan* on which the *Planariæ* are formed, the anatomist may trace the indications of the same constructional principle from the genus *Lineus*, through that of *Borlasia*, *Gordius*, *Meckelia*, *Serpentaria* and *Prostoma*, genera which are characterized by the possession of a long proboscis and short œsophagus, forming a system almost distinct from the great digestive *cæcum*. In passing to the *Planariæ*, these two prehensile structures disappear, and the mouth opens directly, without any intermediate tubular arrangement, into the digestive cavity. The cæcal ramifications of the digestive system of the *Planariæ* are the precise equivalents of the *great digestive cæcum* with its secondary diverticula, as observed in the *Nemertinidæ*.

The anatomy of the *Planariæ* conveys an exact expression, in all its details, of that of the *parenchymatous Entozoa*. The digestive apparatus of the genera *Fasciola* and *Distoma* is conformable to the same type. Like the

* As it would be out of order to enter in this place into a detailed description of the reproductive organs of these worms, no further proof can be adduced, bearing upon the question of the digestive character of the organ which in the text I have denominated "the great digestive cæcum." In the second part of this Report, which I trust will appear in the next year's Volume of the Transactions, some further observations on the reproductive organs will be added in connexion with the subject of the Embryology of the Annelida. At present I only desire to indicate the example of the *Planarian* family, as sufficient to prove that *in them at least*, the digestive cæca, so exactly homologous with the alimentary cæcum of the *Nemertinidæ*, have been shown incontestably to be wholly unconnected with, and independent of, the reproductive system, the anatomy of which, in all its minutest details, may be defined with perfect clearness.

Nemertinidæ, the *Planariæ* are provided with ciliated integuments. This general distribution of vibratile cilia over the cutaneous surface, suggests the inference that the milky contents of the digestive tubules, in common with the blood-proper, undergoes a respiratory change. And lastly, a further departure from the type of the *Nemertinidæ* occurs in the *Cestoid Entozoa*, for in *Tænia* and *Bothriocephalus*, not only the proboscis and œsophagus disappear, *but the mouth also*. The digestive system remains, notwithstanding, essentially the same. By these observations, the author hopes that an addition of some interest and importance is made to our knowledge of the organization of some of the most curious forms of inferior life. The *plan of study* which they are well calculated to suggest, may lead, in the hands of others, to much further and more extensive results. They will suffice, he trusts, to divert the attention of physiologists from the blood-proper as the *exclusive* fluid element of nutrition, to the study of the characters of the great chyl-aqueous system of fluid, of the existence and importance of which, in nearly all invertebrate animals, ample evidence has been adduced in the progress of this Report. They establish the principle formerly enounced, that each constituent element of the living organism, whether *fluid* or *solid*, in its generic and specific phases is governed by one undeviating law. The fluids obey *their* law and the solids *theirs*. Thus the successive members of the zoological series are united at *several* points, *all* component systems of the organism displaying a *consecutiveness* of development, a unity of plan, such that the presence of each in its allotted position is essential to the resultant, symmetrical unity of the whole.

Reproductive System.

No subject within the domain of comparative anatomy has experienced so much neglect as that which relates to the structure of the organs of reproduction in the Annelida. The whole process of multiplication in these worms, as explained by M. Dugès and Sir E. Home, seems little else than a myth or a fable. A romance or a fairy tale, woven in the picturesque language of a modern fiction-writer, could not prove to the imagination of the practical observer more full of mystery and marvel. Since the epoch of these two anatomists, no attempt whatever has at any time been made to determine the true characters of the reproductive organs of the Annelid. Milne-Edwards, to whom science owes no ordinary gratitude, has indeed resolved the enigma of the development of one solitary worm, viz. *Terebella nebulosa*. It is to be wondered at, however, that, while noting the embryological history of this worm, he did not turn to the parent animal and describe the organization of the parts engaged in the production of the new being. It were to serve no purpose of historical interest to reproduce in this place the descriptions of the earlier anatomists. They contain little of what is true and much of what is false. This statement is not made in the spirit of reproach. Dugès' instruments of observation, used too on a little restless worm almost itself microscopic, could not carry the eye to those details of structure through which alone the real connection and dependence of organs was to be tracked. The observations of Sir E. Home, far less faithful and exact, are still less entitled to repetition in this place.

The Annelida are commonly reputed to multiply the species, not alone by the production of young, but also by *fission and gemmation*. With characteristic gravity, for example, the learned Hunterian Professor* relates, that " the power of repairing injuries and reproducing mutilated parts is

* Sections on Invertebrate Animals, vol. i. p. 143.

considerable in the Annelida, and especially in the species of *Lumbricus* and *Nais*, in which it has been variously and extensively tested by the experiments of Bonnet and Spallanzani. A worm cut in two was found to reproduce the tail at the cut end of the cephalic half and form a new head upon the caudal moiety. Bonnet* progressively increased the number of sections in healthy individuals of a small worm (*Lumbricus variegatus*), and when one of these had been divided into twenty-six parts, *almost all of them reproduced the head and tail*!!, and became so many new and perfect individuals. It sometimes happened that both ends of a segment reproduced a *tail*. Wishing to ascertain if the vegetative power was *inexhaustible*, Bonnet cut off the head of one of these worms, and as soon as the new head was completed, he repeated the act; after the eighth decapitation, the unhappy subject was released by death; the execution took effect, the reproductive virtue had been worn out: this series of experiments occupied two summer months. Since many of the smaller kinds of worms and Naids frequently or habitually expose a part of their body, the rest being buried in the earth, both they and their enemies profit by the power of restoration of the parts which may be bitten off! With this power of reproduction of lost extremities is associated that of spontaneous fission in the genus *Nais*. In these little red-blooded worms, the last joint of the body gradually extends and increases to the rest of the animal; its anterior part begins to thicken and to be marked off by a deeper constriction from the penultimate link. In the *Nais proboscidea* a proboscis shoots out from it like that on the head, and it is then detached from the old *Nais*. It often shoots out, previously to its separation, another young one from its own lost joint in a similar way, and three generations of Naids may thus be organically connected, and forming one compound individual."

On the authority of hundreds of observations laboriously repeated at every season of the year, the author of this Report can declare with deliberate firmness, that there is not one word of truth in the above statement. It is because accounts so fabulous have been rendered "respectable" by the fact, that Professor Owen has thrown over them the ægis of his great authority, that they demand a contradiction which may displease by the strength of the language in which it is given.

The following is another illustration of the extraordinary degree to which the groundless fancies of the older observers have taken captive the imagination of the moderns:—"In the class Annelida we still find that gemmation performs a very important part in the act of reproduction; the multiplication of similar segments, which is so remarkable in many members of this group, being almost entirely due to it; and a spontaneous division sometimes taking place by which the parts thus produced are detached from one another, sometimes in such a condition that they must be regarded as perfect individuals, whilst in other cases they seem little more elevated in the scale of animality than are detached ovigerous segments of the *Tænia*. A complete reproduction by gemmation succeeding by spontaneous fission, may be seen to take place in *Nais*, a worm which, though aquatic in its habits, belongs to the order *Terricolæ*. After the number of segments in the body has been greatly multiplied by gemmation, a separation of those of the posterior begins to take place; a constriction forms itself about the beginning of the posterior third of the body, in front of which the alimentary canal undergoes a dilatation, whilst on the segment behind it, a proboscis and eyes are developed, so as to form the head of the young animal which is to be budded off; and in due time, by the narrowing of the constriction, a com-

* Œuvres, vol. i. pp. 117–245. 4to, 1779.

plete separation is effected and the young animal thenceforth leads an independent life. Not unfrequently, however, before its detachment, a new set of segments is developed in front of it, which in like manner is provided with a head and separated from the main body by a partial constriction; and the same process may be repeated a second and even a third time; so that we may have in this animal the extraordinary phænomenon of four worms which are afterwards to exist as separate individuals, united end to end, receiving nourishment by one mouth and possessing one anal orifice. A similar phænomenon has been observed in several genera of the dorsibranchiate order; but the gemmæ thus detached are not complete individuals, for each consists of little else than a generative apparatus, with the addition of locomotive organs; thus bearing a similar relation to the parent stock, which does not form generative organs of its own, to that which is borne by the Medusæ-buds to the Polype-stock.

"In the one case, as in the other, it must be improper to reckon the generative segments of a new generation, since they are merely the 'complements' of the organism that would be incomplete without them.

"As many as six of these generative offsets have been seen in continuity with each other, and with the parent stock, by Prof. Milne-Edwards, the most posterior being evidently the oldest, and one in direct connection with the parent, consisting as yet but of a few segments and being obviously the youngest. A similar detachment of a generative segment has been observed among the *Tubicolæ*. There are several Annelids which may be multiplied by artificial sub-division, each part being able to grow up into the likeness of the perfect animal, though they do not spontaneously reproduce themselves in this mode*."

The *whole* of this subject is not easy of proof; experiments conclusively and unexceptionably conducted must extend over a considerable time, and should be followed out under the most favourable circumstances of leisure and opportunity; a very large portion of the subject may, however, even with our present acquaintance with the habits of the Annelida, be very confidently disposed of. 1st, as to the *spontaneous division of the body.—It is true* that towards the latter end of every summer two species of worms are multiplied by a cutting across of the body at one or more points. If the fission occurs at more than one point, the animal becomes of course divided into more than two pieces. This circumstance seldom occurs. The fission in *Arenicola* generally occurs somewhere within the middle third of the body, securing a few branchial tufts for each fragment. The tail however is sometimes detached, and sometimes the division happens very near the head. This process, both in *Nais* and *Arenicola*, happens during July and August. The cephalic and caudal pieces in *Arenicola* continue for some time to writhe in the sand, somewhat further down in the soil from the surface than the perfect individuals. Towards September, the fragments, both *that* attached to the head and *that* belonging to the tail, dissolve away ring by ring, and finally disappear by decomposition. If the fragment examined be that of the tail, it will be observed, at the point of separation, to exhibit an *eversion* of the edges, placing the alimentary canal exteriorly; and a very evident increase of size in the vessels also occurs, accompanied by a tumified state of all the structures of the part. From this latter fact it is easy to be misled into the idea that the vessels can become enlarged for no other purpose than that of repairing the injury done by the fission, or perchance of reproducing the part detached by that process. Such would naturally be the meaning which a physiologist would attach to the swollen appearance of the blood-

* Carpenter's Principles of Physiology, 3rd ed. p. 934, par. 714 *a*.

vessels. But such is not the conclusion to which the careful practical observer is conducted by the study of the actual phænomena of the process. It is of course indisputable that nature accomplishes some adequate object by the fission of the body of the worm; but that object, whatever else it be, is unquestionably not that of multiplying the species. The tail-fragment *never*, as can be proved by easy observation, produces a single new ring or segment of the body. If this be true, how completely improbable must be the statement that the headless piece is capable of reconstructing a *new head*! In *Arenicola* and *Nais* the author can confidently declare that such reproductive properties as those implied in the reformation, and that too by a remnant of an integral part of the body, do not exist. It is equally inaccurate to maintain that a new tail is formed by the cephalic fragment. This half of the divided worm, like the former, gradually presents evidences of decay; it becomes less and less irritable, the muscles and integuments begin to decompose, the blood-vessels of the branchiæ become black, and the whole disappears by the dissolution of the structures.

If, as is commonly affirmed by zootomists, each individual ring of the body constituted a real organic submultiple of the entire animal, the possibility of its independent existence could be readily conceived. This however is not the case. In *Arenicola*, *Nais* and *Terebella*, and many other species, the reproductive organs are limited to the anterior two-thirds of the body. They do not exist in the caudal segment. When this latter part therefore is detached from the cephalic extremity, it is evident that it cannot be regarded as a *totum integrum*, a perfect animal in miniature. It wants the most important and essential components of a perfect organism—the generative apparatus, without which the mind cannot realise the conception of distinct individuality. In *Nais filiformis* the division most frequently happens at a short distance from the head, through the very middle of the glandular mass of the reproductive organs, tubes being cut across, and the testicular glands being bisected. These extraordinary facts, correctly interpreted, prove clearly that there can be no *method* in this spontaneous fission of the body, no one situation selected in preference to another, no including of one system of organs and an excluding of another, no definite intelligible ruling principle. What then can be the meaning of such an extraordinary freak of nature? Is it an accident which befalls only a few luckless individuals? The sand of the sea-shore and the mud of the freshwater pools are thickly strewn with the mutilated bodies of these worms, the former situation of the Lug, and the latter of the Naiades. It is a catastrophe, in which every autumn involves the whole community.

The following interpretation of the above facts, the truth of which cannot be disputed, may be presented as best accordant with what is at present known with reference to the history of the reproductive process in these worms:—

1st. These Annelids are *annuals*; the term of existence is completed when the organic cycle is *once* accomplished. They are born during the latter months of one summer, and survive the winter, attain to the maturity of growth, reproduce the species, and die by the spontaneous subdivision of the body into fragments on the arrival of the same season of the succeeding year. This brief round comprehends the history of each individual. Since these worms are monœcious, each shares the common fate. Each contributes by its own death to the multiplication of the species; the species being multiplied, the ends of its own existence are accomplished.

2nd. For some time before the fission of the body occurs, the process of the maturation of the ova is proceeding. Arrived at the matured phase, they

escape from the ovarian system into the free space of the peritoneal cavity, wherein they sojourn until the next phase of their growth has been attained. It is during the period marked by the presence of true ova in the chamber of the peritoneum, floating in the contained fluid, that the division of the body of the parent animal takes place. In each fragment is nestled, incubated, a considerable number of ova. Filled still by the fluid of the peritoneal cavity, each fragment becomes subservient to the end of hatching the young. It resists decomposition only for the period required for the accomplishment of this purpose. When the ova are committed to the sand, the fragment rapidly disappears by putrefaction. The fission of the body, thus interpreted, becomes the last act of the parental worm, since the portions into which the body is subdivided by fission, *never take food.* The proboscis of the cephalic fragment is never more protruded to take in sand. With the fission the necessity for food terminates. If, on the contrary, the division of the body were the first step of a real reproductive operation, characterized by the superaddition of new segments to the body, the reconstruction of lost heads, and the manufacture anew of departed tails, a resort to physiological arguments were little required to prove that each fragment *should* grow voracious, and consume extra supplies of nourishment, in order to provide the necessary pabulum for the reparation of the mutilated parts. As this is not the fact, the inference is clear that the division of the body is not the prelude to a series of reconstructive operations by which *parts* are made "*wholes*," or mutilations repaired. The experiment of artificially bisecting the body of a Nereid or an Earth-worm, replacing the divided halves with care again in their native habitats, invariably, in the author's hands, has led to the following results.

The *cephalic half*, by this division of the body, does not lose the power of locomotion. In a few days after the operation it begins to grow less active and vigorous in its movements; the annulus at the point of division begins to contract and wither; in process of a few more hours it dies—it mortifies away. This process of dissolution creeps in the direction of the head from one segmental ring of the body to the other, until finally the cephalic remnant ceases to manifest any signs of life.

The tail-half immediately loses the power of advancing; it writhes on one spot, and that only on contact of some external body; its motions become *excited*, not *voluntary*; it never reacquires the power of swallowing earth. The process of decay begins much sooner than in the cephalic half, and extends in the direction of the tail, implicating one ring after another more rapidly, until the whole is involved in decay*.

If the Annelid were really endowed with the reproductive properties, which by the most recent and distinguished naturalists they are reputed to possess, such marvellous powers would undeniably have been called into activity by the artificial division of the body.

From the analogy of the two species, viz. *Arenicola* and *Nais,* on which the author's observations have been chiefly conducted, the conclusion may be deduced that the "fission of the body" in every other species of Annelida in which it occurs, has for object in like manner to protect and incubate the

* I have a distinct remembrance that many years ago, whilst studying physiology under the zealous teachership of Mr. Grainger, experiments were related by that distinguished physiologist, and conducted by himself, with a view to resolve the enigma of the "mysterious tales" popularly prevalent with reference to the reproductive powers of the worms, from which he drew conclusions precisely the same as those expressed in the text. I can now add my testimony to the correctness of the observations, instituted for a different purpose, and so long ago, by one who has contributed not a little to the advance of physiological science.

ova. In this indirect sense, and that alone, can the "spontaneous division" of the body in the Annelid be regarded as participating in the reproductive operations.

All that is known of the embryology of the Annelida has been within recent years only contributed by Milne-Edwards. The illustrations given by him delineate the successive stages presented by the young of *Terebella nebulosa* in the process of growth. As the author of this Report has yet enjoyed few opportunities of studying the development of the young, he proposes for the present to omit entirely that department of his subject, hoping that on some future occasion he shall be able to complete the history of the British Annelids by the addition, to the embryology of the worms, of the results of his own personal inquiries. Nothing would be here gained by the further repetition of the oft-repeated descriptions of Dugès with reference to the structure of the generative organs of the Leech and the Naid. It is remarkable to relate, that no anatomist, from the epochs of Dugès and Sir Everard Home to the present time, has perceived that these descriptions comprise only *one-half* of the sexual organs of these worms. It is extraordinary that none could discover the physiological necessity, even in hermaphrodite organisms, for a feminine system, for some ovarian apparatus. These descriptions relate only, and that not by any means accurately, to the masculine elements.

It will be afterwards proved that every anatomist who has ever investigated the organization of the Annelida, has mistaken the true utricular ovaria for the *respiratory sacculi.* If the ultimate structure of these so-called sacculi had at any time been made the subject of minute examination, their real nature as the female generative system could not have eluded the eye. M. Quatrefages, whose figures have been copied into the last and best edition (Crochard's) of the 'Règne Animal,' described these ovarian sacculi as "les poches secrétrices venant s'ouvrir sur le dos par les canaux renflés." The same author figures in the same great work the corresponding organs of the Leech, and speaks of *them* as "les poches secrétrices latérales avec leur cæcum." Both the figures and the description prove that M. Quatrefages could not have attained to the remotest conception of the true significance of these organs. Nor do the figures given in the 'Règne Animal,' costly and beautiful as they are as works of art, convey any but the most egregiously erroneous view of the structure and anatomical relations of these organs. All observers are liable to error, but the errors of distinguished men, at once ornaments and authorities in the walks to which their genius may have been dedicated, are mischievous in proportion to the height from which they descend, and should be combated at once with unmeasured strength of language. Numerous examples might be quoted from every branch of science, of the pernicious influence which an undue reverence for authority has exercised on the progress of knowledge. In no department of observational science has hereditary error grown so venerable by repetition as in that which embraces the Annelidan division of comparative anatomy.

The title of the author of this Report to the merit of having added something *new* to the traditionary lore transmitted through a long succession of systematic writers, can only be determined by a comparison of his descriptions and figures with those given in the works of the best and most recent writers. In the succeeding account he is desirous to describe minutely and at length the results of his own investigations. This will prove more acceptable to science than the repetition of that which has already been so often repeated. The dissection of the reproductive organs in these animals is attended by many practical difficulties; it has therefore proved impossible

to describe in minute detail the specific varieties under which these organs occur in the class. Leading generic types will however be described, which will serve to convey to the mind a clear conception of the structural laws according to which this system of organs is constructed.

Those of the Leech, *Lumbricus*, *Nais*, *Arenicola*, *Terebella* and *Albione*, will conduct the physiologist far towards a full and complete conception of the ultimate anatomy and relations of the reproductive organs in all other Annelida. Each description will be preceded by a summary of what has been up to the present date taught by the best systematic authors with reference to these organs. The succeeding account is transferred from the work of Mr. Rymer Jones, the best digest of comparative anatomy at present known. "In the Leech, the glands which furnish the masculine fluid are about eighteen in number, arranged in pairs upon the floor of the visceral cavity. Along the external edge of each series there runs a common canal, or *vas deferens*, which receives the secretion furnished by all the testicular masses, placed upon the same side of the median line, and conveys it to a receptacle whence it accumulates. The two reservoirs, or *vesiculæ seminales*, if we may so call them, communicate with a muscular bulb situated at the root of the male organ. This organ is frequently found protruded from the body after death; it is a slender tubular filament which communicates by its origin with a contractile bulb, and when retracted, is lodged in a muscular sheath. The male apparatus is thus complete. The fecundating secretion derived from the double row of testes is collected by the two *vasa deferentia* and lodged in two globular receptacles situated on either side of the bulb; it is thence conveyed into the muscular cavity which is placed at the root of the male organ of excitement, through which it is ultimately ejected.*"

The foregoing description, quoted from the work of Mr. Rymer Jones, is founded upon the original dissections of M. Dugès; it relates exclusively to the male apparatus, and to its *general* accuracy the author can testify from the results of his own dissections. The passage which now follows purports to be descriptive of the correlative feminine system of the Leech, and is taken from the same excellent work. To it special attention is invited. "The ovigerous or female organs of the Leech are *more simple in their structure* than those which constitute the male system; they open externally by a small orifice situated immediately behind the aperture; the penis is protruded, the two openings being separated by the intervention of about five of the ventral rings of the body. The vulva or external canal, leads into a pear-shaped membranous bag, which is usually, but improperly, named the uterus. Appended to the bottom of this organ is a convoluted canal which communicates with two round whitish bodies; *these are ovaria*. The germs, therefore, which are formed in the ovarian corpuscles, escape through the tortuous duct into the uterus, where they are detained for some time prior to their ultimate expulsion from the body. The exact nature of the uterine sacculus, as it is called, is imperfectly understood; some regard it as a mere receptacle wherein the seminal fluid of the male is received and retained until the ova come in contact with it as they pass out of the body, and thus subjected to its vivifying influence; other physiologists believe that the germs escape from the ovaria in a very immature condition, and suppose that during their sojourn in this cavity they attain to more complete development before they are ripe for exclusion; while some writers go so far as to assert that leeches are strictly viviparous, inasmuch as living young have been detected in the interior of this viscus; but all these suppositions are easily reconcileable with each other: there is no doubt the seminal liquor is deposited in this reservoir

* Animal Kingdom, by Rymer Jones, p. 200.

during the congress of two individuals; neither would any one dispute that the ova are collected in the same cavity before they are expelled from the body; as to the discussion whether the young are born alive or not, or, as it is generally expressed, whether leeches are oviparous or viviparous, it is in this case merely a question of words, for in a physiological point of view it can make not the slightest difference whether the ova are expelled as such, or whether, owing to their being retained by accidental circumstances until they are hatched internally, the young leeches make their appearance in a living state*."

What is described in the preceding passage is *rightly* described. There *is* in nature what it purports to define—a median pear-shaped sacculus, from the fundus of which a small coiled cæcal process depends. But is it possible, on any physiological principle, that this simple sacculus can be the feminine correlate of that complex, elaborate and highly-developed testicular apparatus previously described in the same animal? Is it not *à priori* improbable that one moiety of the reproductive system should coincide to the Annelidan type, namely, that of exhibiting a tendency to segmental repetition in a longitudinal series,—while the other, and unquestionably the more important half, should be concentrated into the narrow limits of a solitary sacculus appended only to one ring of the body? The median sacculus originally discovered by M. Dugès *does* exist, but is constituted, as will afterwards be shown, the least important constituent of the generative system. Desirous to assign to M. Dugès the credit to which he is really entitled, it is now proposed to quote the description given by this anatomist of those organs in the Leech which he was the first to discover, and which he, and, after him, *all* subsequent comparative anatomists have designated "*the respiratory sacculi.*" It will be seen that his descriptive statement, with reference to these "respiratory sacculi," agrees in its leading points with the anatomical account which the author will afterwards have to present of the true and indisputable feminine element of the reproductive system of the Leech.

"It has already been mentioned, that in the Abranchiate Annelidans, the organs provided for respiration are a *series of membranous pouches*, communicating externally by narrow ducts or spiracles, as they might be termed, into which *aërated water* is freely admitted. These respiratory sacculi in the Leech are about thirty-four in number, seventeen being visible on each side of the body; they are extremely vascular; and in connection with every one of them there is a long glandular-looking appendage, which was looked upon until lately as being intended to furnish some important secretion, but which recent discoveries have shown to be connected with the propulsion of the blood over the walls of the breathing vesicle." "On examining minutely one of the respiratory pouches, its membranous walls will be seen to be covered with very fine vascular ramifications, derived from two sources: the latero-abdominal vessel gives off a branch, which is distributed upon the respiratory sacculus; and there is another very flexuous vsscular loop, derived from the lateral vessel itself, which terminates by ramifying upon the vesicle in a similar manner. The walls of the loop are extremely thick and highly irritable; but on tearing across, the internal cavity or canal by which it is perforated, is seen to be of comparatively small diameter, so that we are not surprised that, although such appendages to the respiratory sacs were detected and well delineated by Delle Chiaje and Moquin-Tandon, their nature was unknown, and they were supposed to be glandular bodies appropriated to some undiscovered use. From the arrangement above described, it is evident that small circular currents of blood exist, which are independent, to a certain

* *Op. cit.* p. 201.

extent, of the general circulation; since opposite to each membranous bag a portion of the fluid contained in the lateral vessel is given off through the muscular tube, which thus resembles a pulmonary heart, and after being distributed over the walls of the respiratory sacculi, and in this manner exposed to the influence of oxygen, the blood returns into the general circulation*." While the description of M. Dugès, just cited, does not very untruly represent the mere anatomical characters of the parts to which it relates, the error of interpretation involved in his views, the fact that he saw in the wondrous structure displayed by these parts a fantastic mechanism for respiration, is as extraordinary as any false conception ever known in the history of comparative anatomy.

It will subsequently be found that his marvellous muscular fusiform hearts for circulating the blood over the *so-called* respiratory sacculi, are true and unquestionable *ovarian utricles*, proved to be such by the discovery in them of veritable ova.

The *respiratory sacculus* (of Dugès), scrutinized through the searching eye of the modern microscope, resolves itself into a simple vesicle pendent to the ovario-uterine system; and the extraordinary blood-vessels of M. Dugès appear only as *tubes* connected with these two parts of the female apparatus.

The author will now proceed to describe the whole reproductive system of the Leech as deciphered by his own investigations. Having once seized the true key to the interpretation of the physiological meaning of the several component elements of this system, the mere anatomical process of determining its limits became easy of execution. In the ordinary medicinal leech the whole apparatus presents the same characters in every individual. The leech is therefore monœcious or hermaphrodite. The union of two individuals is however essential to impregnation. This rule may be stated to be applicable to the great majority, if not absolutely to all, of the Annelida. The masculine and feminine moieties of the system bear to each other a proportion of equality. The testicular bodies and ovario-uterine organules are nearly equal in number, the latter slightly preponderating over the former.

The testes are observed under the character of small white granular bodies, disposed at short distances in a longitudinal series on either side of the ventral median line of the body (Plate VIII. fig. 65 *a*, *a*, *a*, &c.). When forcibly compressed, a white fluid exudes, which under the microscope is found to consist of nothing but sperm-cells (C.) in various stages of evolution. To each of these testicular bodies two (fig. 65 *c d*, *c d*, &c.) minute threads are attached. The larger and more obvious of these threads (fig. 65 *c*) extends outwards at right angles with the median line, and joins a considerable chord running parallel with the median line (*f*). Examined in section, both the transverse threads and longitudinal chord prove to be tubes filled with fluid thickly charged with sperm-cells, a true male secretion. The longitudinal tube (*f*) is common to *all* the testicular bodies; it begins at the most posteriorly situated of these bodies, and ends in that most anteriorly placed, median and azygos (*j*), to which the intromittent organ is appended; meeting at this mesial organ the corresponding duct of the opposite side. In addition to the tubulus just described as proceeding from the testes, another and much smaller one (*d*, *d*, &c.) may be detected on minute dissection running directly outwards, crossing underneath the large longitudinal duct (*f*, *f*) and becoming united (as at *g*, *g*, *g*) to the base of the ovarian utricle. Traced in the direction of the head, the longitudinal duct is seen to enter into a glandular body (*h*), which in size is considerably greater than the testes situated

* *Op. cit.* p. 198.

posteriorly to it on the same side. In minute structure this body is precisely the same as the bodies of the testicular series; like them it is filled with sperm-fluid; the interior is a cavity. The secreting glandular structure is disposed around the circumference; the secreted product is thrown into the enclosed hollow. This description applies also in every particular to the other testicular bodies, which are like the former, hollow orbicular glands. The large longitudinal duct which serves as a common channel of communication between all the testes, emerges out of the gland (*h*) under the character of a duct of greatly reduced size (*i*). This small tubular thread, traced with minute care, may be followed into the median glandule (*j*) to which the penis (*k*) is appended. In the median line also, and some little distance posteriorly to the body just described, may be remarked a pear-shaped sacculus (*l*) from the unattached fundus of which a cæcal coiled tubule (*m*) is prolonged. Between this saccular and the other parts of the reproductive system, no communication of any description can be discovered. It seems simply destined to receive the intromittent organ developed in connexion with the gland situated in advance of it on the median line.

It may be inferred from the character of the whole system of the testicular bodies, that the penis is not an ejaculatory organ; it seems subservient only to the purposes of sexual stimulation. By all anatomists, from the date of the first description of M. Dugès, this *sacculus* has been regarded as a uterus, and as, in fact, constituting the whole of the female element of the generative system. The convoluted cæcal tubule pendent from the fundus of this sacculus, including some undiscoverable gland structures on either side of it, are commonly indicated as the ovaria. Such anatomists, whilst entertaining opinions so remote from the truth, and withal so little probable on physiological grounds, never could have *seen* these parts. An ovarian system so utterly disproportionate to the testicular, *if it were true*, would find no precedent or parallel in the whole series of invertebrate animals.

In all hermaphrodite animals the female elements of the generative organs are invariably superior in size, more elaborately organized, and more important as constituent parts of the whole organism, than the male: wherefore should the converse of this rule obtain in the Annelida? A cursory glance at the organic necessities of the animal system should have sufficed to convince the physiologist that such a simply organized sac, so uncomplicated in structure, so unprovided with stromatous tissue for the production and development of ova, could not have proved adequate to those profound functions involving in intimate sympathy every other of the organism which are concerned in the continuation of the species. It was the necessity, thus perceived on theoretical grounds, for some series of organs which would *reasonably* answer to the general characters of a female system, which first led the author to the discovery of that which now remains to be explained.

In the Leech, the female system consists of a greater number of separate parts than the male, amounting to fifteen or seventeen on either side, while the testicular bodies are only nine. This system is composed of a linear succession of a bag-pipe shape, membranous sacculi (fig. 65 *b*, *b*, *b*, &c.), contracting at both ends into two separate ducts. One of these ducts (*l*, *l*, *l*, &c.) terminates an orifice communicating externally. It is through this orifice that the ova and young escape from the ovarian utricle into the external medium. In the Leech, the ova in *this* duct, in every case yet examined, present an obviously greater degree of development than those which are found in the duct (*g*, *g*, B) which communicates with the neighbouring testis. At certain seasons of the year, in the Earth-worm, this duct, which may be called the *inferior* duct of the ovario-uterine organ, is crowded with living young, emer-

ging from the ova, and in process of final extrusion through the external orifice. The *hatched young* in the Leech have never yet been seen actually by the author in this situation, although the parts are accurately correspondent in the two worms. He cannot yet therefore state of the Leech what he can from actual observation of the Earth-worm, that it is viviparous: the *superior* duct (*d*, *d*, &c.) of each ovarian uterus passes underneath the common longitudinal chord (*f*, *f*) and opens into the true testicular duct (*c*, *c*, &c.), the two channels becoming united into one just before entering the substance of the gland. It is desirable here to warn the anatomist, that in practice the demonstration of this fact demands great patience and minuteness of dissection. At B, fig. 65, the ovarian uterus is seen still further magnified.

The author now desires to solicit special attention while he attempts to explain the nature of the connexion which, according to his view, subsists between the male organ or testis (fig. 65, *a*, *a*) on the one hand, and the egg-producing and egg-incubating organ (fig. 65, *b*, *b*, &c.) or ovarian uterus on the other. It will, he trusts, suffice to elucidate satisfactorily the mechanism of *self-impregnation*. The testicular bodies (*a*, *a*) secrete a true sperm fluid, the cells of which can readily be detected by the eye both in the duct (*c*, *c*) which leads to the great longitudinal chord, and in that (*d*, *d*) which conducts (as seen at *g*, *g* and B, *g*) into the ovarian uterus. The male seminal fluid travels from the testes into the ovarian uterus along the superior of these ducts. It may be actually detected in the cavity of this latter organ, where it comes into immediate contact with the ova, whereby impregnation results. The ova thus fertilized travel gradually onwards and reach the inferior half (B, *m*) of the ovarian uterus. As in the Leech, these ova may be discovered *as ova* at a point in the oviduct very near the outlet, it is probable that this Annelid is oviparous. This fact, which is little material, may be readily determined by examination instituted at the right season. The curved ovario-uterine membranous organ is really the part to which Dugès applied the name of "the cardiac vasiform heart," and which M. Quatrefages has denominated "la poche secrétrice!!" Dugès made a near approach to a correct *descriptive* anatomy of this organ. Quatrefages' delineations are extravagantly erroneous. To each ovarian uterus a beautifully delicate vesicle (*e*, *e*, *e* and B, *o*) is attached. It is connected with the superior duct, or that which leads directly from the testis into the ovario-uterine saccule by means of a very slender tubule (B, *n*) rising from the vesicle (B, *o*). This vesicle is the far-famed "respiratory sacculus" of the Leech; the duct (*n*) communicating between it and the superior half (B) of the ovarian uterus is the wondrous *respiratory heart-vessel*, which for half a century has challenged the admiration of anatomists!

Let it now be seen what rational and probable physiological explanation these parts will bear. In the first place, it is obvious that there exists in this Annelid a direct communication by means of an open duct between the male and female elements of the reproductive system; that this system opens externally *only* at the orifice of the oviduct (*l*, *l* and B, *q*); that these orifices are designed for the extrusion of the ova or young from the body of the parent, and not for the reception of the sperm-fluid into the ovario-uterine tract; that the male fertilizing secretion passes directly along the duct (*d*, *d* and B, *g*) into the ovarian uterus (*b*, *b*); and that thus the process of *self*-impregnation is *literally* accomplished, for it is not the sperm-fluid of *another* individual that fecundates the ova, but that of the *same* individual.

This conclusion may be affirmed with confidence, since the median copulative saccule (*l*, fig. 65) into which the intromittent organ (*k*) of *another*

individual is inserted terminates in a convoluted cæcal tubulus. Between this median organ and the great bilateral series of ovario-uterine organs there is no communication whatever. If therefore during the union of two individuals a fluid is emitted by the male organ (*k*) into the interior of the sacculus (*l*), it requires no further argument to show that it can proceed no further, that it can reach no *other* part of the reproductive system. In congress therefore these two parts can subserve no other than the purposes of first mechanically uniting the individuals, and secondly of stimulating the sexual organs. During those periods when the fertilizing fluid is not required for the office of fecundation, it is probably discharged externally as a superfluous excretion in part through the intromittent organ (*k*). According to this explanation, to the larger testicular bodies (*h*, *h* and *j*) should be assigned the mechanical uses only of seminal receptacles, compressing what they may contain, either backwards into the ovario-uterine organs, or forwards to be expelled through the penis as an excretion. The penis therefore is the only means *common* to the whole male system by which it communicates with the exterior, the so-called "respiratory sacculi," as subsequently to be explained, being the means by which each testis separately communicates with the exterior.

The sperm-cells of the Leech are represented at C (fig. 65) in their several phases of evolution.

It is here essential to add that the *ova* are first produced in a *stromatous layer* which constitutes one of the coats of the ovarian uterus (B), and that a large number of them are contained in a common capsule (B, *p*) until they attain a certain degree of development, after which they may be recognised near the outlet of the oviduct in a *single* and free state.

Ova are never found in the so-called "respiratory sacculus" (B, *o*, *e*, *e*, *e*), but, on the contrary and invariably, a small quantity of *sperm-fluid*: each of these sacs is perforated (as at *r*, B) at the point where it is attached to the integument by an orifice which opens directly *externally*. This vesicle, which from the date of the writings of M. Dugès has been rapturously described as the "respiratory sac" of the Leech, correctly interpreted, is a true *vesicula seminalis*. It is designed to receive the superfluous portion of the sperm secretion as it passes from the testis to the ovarian uterus. Through the orifice (*r*, B) this unrequired portion is discharged externally. Spermatozoa can always be discovered in the interior of these vesicles.

Their parietes are very scantily supplied with blood-vessels! What then becomes of the blood so profusely poured over these parts by the contractile thick-walled vessels of Dugès?

On the authority of Mr. Brightwell of Norwich, it is generally held that the leeches are *oviparous*. His description bears the stamp of circumstantial accuracy and truth, and tends to confirm the inferences which the author of this Report has ventured to draw from anatomical investigations.

Mr. Brightwell relates that "early in March of the present year (1841) about seventy specimens of a small leech were taken from the back fin of a roach caught in the river Wensum. They were the *Hæmocharis piscium* and *H. geometra* of authors. These leeches being placed by themselves in a glass vessel, and having fresh water put to them every morning, several instances of sexual connexion were observed to take place immediately after the fresh water was added, one of the leeches suddenly twisting itself round the neck of another, and closing upon a longitudinal opening which at this time was very conspicuous in the neck of each. During this union a white substance could be perceived on the side of the part where the bodies were connected. They continued united generally several hours, and in one case

during the whole day. When the leeches separated, a white filmy substance was detached from the parts where they had been united, which in one case had the appearance of eggs, but from subsequent observation it was found to be a film in which the eggs were enveloped. Within twenty-four hours after the union took place, eggs were deposited and were found firmly attached to the sides of the glass vessel. By an experiment made with a pair which were kept separate for that purpose, twelve eggs were found to proceed from two individuals. These eggs were semitransparent, of a reddish brown colour, oblong-oval, with one end truncated; they were covered with a white filmy web-like secretion, and had longitudinal elevated ridges on the sides. The shells of the eggs were found, on dissection, to be extremely hard. On the thirtieth day after the eggs were deposited the first young leech made its appearance. Each egg produced only one leech; this was ascertained by detaching an egg and keeping it in a glass by itself, when one leech only proceeded from it. The young leeches were of the size of a small thread, about one-third of an inch long, and appeared perfectly formed; the brown annular markings of the body, the longitudinal lines upon the posterior disc, and the four eyes in the anterior disc or sucker being clearly visible."

Mr. Brightwell remarks with reference to the Horse-leech, *Hæmopis Sanguisorba* (Sav.), which is common in our ponds and ditches, "that it is probably oviparous. We have found its young, in an early stage, in the same places as the adult, but never adhering to the parent." He further states with regard to the medicinal leech, "that a dealer in Norwich keeps a stock of about 50,000 in two large tanks of water, floored with soft clay, in which the leeches burrow. On examining these tanks we found many capsules or ova deposits of the leech, which the owner, ignorant of their nature, stated to be at times very numerous, but which he had neglected and generally destroyed."

Of another species of leech (*Nephelis vulgaris*, Sav.), he states, "This species abounds in all our fresh waters, and the brown capsules containing the ova may be constantly found on the underside of the leaves of water-plants among the ova of the freshwater *helices.* We have kept several species through the summer, and the following are our notes as to the deposit of the ova and the development of the young. On the 2nd of June *H. vulgaris* deposited one capsule containing *ova*; on the 5th another; on the 10th another; and on the 15th two more, each of them containing from seven to ten eggs. On the 22nd the young appeared in the capsule deposited on the 2nd, and on the 13th of July they emerged from the capsule, and in six weeks were fully developed and left the capsule. Examining the young of this species with a power of about sixty linear, we detected a Cypris and four specimens of a common rotiferous animalcule in its stomach, one of the Rotifera being still alive."

Of *Nephelis tessellata* the same observer states, "Müller says the female is sometimes filled with 300 young ones. The abdomen of our species was, when captured, covered with young, which adhered solely to the posterior disc. We kept this specimen from the 24th of June to the 28th of August, when it died. The young remained attached to the parent during all this time, and we took some pains to ascertain their exact number, and found they amounted to 143. We never saw the parents or the young ones take any food. The young differed altogether in colour from the parent, the latter being a deep green, the former a light ash-colour. The abdomen of the parent had no pouch, but was much expanded by the adhesion of so numerous a progeny, so much so as to make the form appear very different from the young *."

* Annals and Magazine of Natural History, 1841.

About many of the foregoing observations cited on the authority of Mr. Brightwell, there is an air of *à priori* improbability. They certainly cannot be admitted in science until confirmed by other observers aware of the anatomical discoveries announced in this memoir. Since *each* ovario-uterine organ has its own oviduct through which it extrudes its ova, it is reasonable to suppose that these ova, *when* extruded, would not be found as a defined ring-like mass encircling the mid-region of the body as commonly stated, and which is said to be thrown off by violent efforts on the part of the animal, the body being withdrawn from within it. A sort of cocoon, open at both extremities, is said *thus* to be produced, which contains from twelve to fourteen ova, enclosed in a protecting substance furnished by the mucous glands of the parent; and the young, after their escape from the ova, quit the cocoon through the openings left by its body. It must be repeated that all this account requires to be confirmed by a trustworthy observer.

The author has been more fortunate in unravelling the reproductive operations of the *Earth-worm*. Between this worm and the Leech there exists a most remarkable resemblance as regards the structure and distribution of the utero-ovarian system. In *Lumbricus* however one prominent and essential point of difference is at once observed. Here the testicular bodies are arranged in a longitudinal series as in the Leech, but concentrated into a considerable glandular mass around the œsophagus and in front of the gizzard. It is quite evident from this arrangement that a bisection transversely of this worm would leave two halves, both of which would be wanting in a paramount constituent of the organism.

Before proceeding to describe the results to which the author has been led by his recent investigations into the anatomy of the Earth-worm, it is desirable, first, to present a summary of what has been taught on this subject up to the date of the present Report. Mr. Rymer Jones observes*, "Few points connected with the history of the Earth-worm have given rise to so much speculation as the manner of their reproduction. The generative organs have long been known to be lodged in the anterior part of the body, their position being indicated externally by a considerable enlargement or swelling which extends from the seventh to about the fourteenth segment, counting from that in which the mouth is situated. On opening this portion of the animal, a variable number of white masses are found attached to the sides of a crop and gizzard, which have long, by general consent, been looked upon as forming the reproductive system; some having been regarded as representing the testes, others as the ovaria; yet so delicate are the connexions which unite these glandular masses, and such is the difficulty of tracing the ducts by which they communicate with the interior of the body, that the functions to which they are individually appropriated have given rise to much discussion. The *Lumbrici* have been generally acknowledged to be hermaphrodite, that is, possessed of organs adapted both to the formation and the fertilization of the ova; and it is likewise well understood that the congress of two individuals is essential to the fecundity of both, as in the earlier months; the mode in which they copulate is a matter of constant observation. At such times two of these animals are found to come partially out of the ground from contiguous holes, and applying together those segments of their bodies in which the generative organs are situated, are observed to remain for a considerable time in contact, joined to each other by a quantity of frothy spume which is poured out in the neighbourhood of the sexual organs. No organs of intromission, however, have ever been distinguished, neither until recently had the canals communicating between the

* *Op. cit.* p. 207.

sexual orifices and the testicular or ovarian masses been satisfactorily traced; so that Sir Everard Home was induced to believe that in the kind of intercourse above alluded to, there was *no* transmission of impregnating fluid from one animal to another, *but that the excitement produced by mutual contact caused both the ovaria and the testes to burst**, so that the ovaria escaping into the cells of the body become there mingled with the spermatic secretion, and being thus fertilized, the ova were hatched internally, and the young, having been retained for some time in the cells between the intestine and the skin, were ultimately ejected through apertures which were supposed to exist in the vicinity of the tail.

"There is however little doubt that what Sir E. Home conceived to be young earth-worms were parasitic Entozoa, and that in the mode of their propagation, the animals we are describing exhibit but little deviation from what we have already seen in the Leech.

"According to M. Dugès the testes are placed in successive segments of the body, from the seventh backwards; they vary in number in different individuals from two to seven; but whether this variety depends upon a difference of species, or is only caused by the posterior pairs becoming atrophied when not in use, is undetermined. Each testis is fixed to the bottom of the ring, in which it is placed by a short tubular pedicle, that opens externally by a very minute pore through which a milky fluid can be squeezed. The testicular vesicles of the same side of the body all communicate by a common canal, and the seminal fluid, which, like the seminal secretion of other animals, contains animalcules, can readily be made to pass from one to the other.

"The ovaria are eight large white masses of a glandular texture, from which arise two delicate tubes or oviducts; these have no connexion with the testes, but running backwards, they become dilated into two small vesicles at their termination, and open by two apertures or *vulvæ* seen externally upon the sixteenth segment of the body; *in these ducts eggs have been detected as large as pins' heads!* The eggs are laid when two or three lines in length. In fig. 85, A†, one of them, enclosing a mature embryo, is delineated; its top is seen to be closed by a peculiar valve-like structure adapted to facilitate the escape of the worm, and opening (fig. 85, B) to permit its egress. Another remarkable circumstance observable in these eggs is, that they very generally contain double yolks, and consequently two germs, so that a couple of young ones is generally produced from each."

By another distinguished systematic writer the following account is given with reference to the mechanism of reproduction in the Earth-worm:—"In the Earth-worm, towards the end of the summer, there is developed around the body a thick and broad belt; this is an apparatus for suction, by which the worms are held together during congress. It is remarkable that the ova do not escape through the ducts which serve to convey the spermatic fluid to the ovaria; but *the ovaria burst* when distended with mature ova, and allow their contents to be dispersed through the interior of the animal. In this respect the process of reproduction in the Earth-worm bears a striking analogy to that which we have witnessed in the flowering plants; for in the latter the fertilizing influence is transmitted down the minute canals of the style, and the seeds escape when ripe by the dehiscence of the walls of their envelope. The ova of the Earth-worm pass backwards between the integument and intestine to the anal extremity; and in their progress they gradually undergo their development and are expelled from their parent, either as com-

* The italics are mine.

† At p. 909 of the Animal Kingdom, by Mr. Rymer Jones.

pletely formed worms, or surrounded by a dense and tough case which gives them the character of pupæ. Whether they are produced in the perfect or in the pupal form, depends on the nature of the soil which the worms inhabit. In a light and loose soil the young quit the parent prepared to act for themselves; but in a tough clayey soil they continue the pupal form for some time, so as to arrive at a still higher degree of development, before commencing to maintain an independent existence*." It is thus seen that Mr. Rymer Jones has copied from Sir E. Home and M. Dugès, and Dr. Carpenter has copied from Mr. Rymer Jones, neither writer having attempted to determine the truth or falsehood of the statements which he was transmitting to another generation. Thus ever has error been propagated.

All that is true in the original description of Dugès with regard to the reproductive organs of the Earth-worm, amounts to no more than what the most cursory dissector may readily verify, viz. that there exists near the base of the œsophagus a mass of glandular bodies, which are described as ovaria, and which, when the contents are mature, are said to *burst*. It is no severity of criticism to remark that this latter idea indicates a very rude state of physiological knowledge on the part of those by whom it is entertained. The dehiscence of large vital organs, like the ovaria, is an occurrence which has never been credibly authenticated in the animal kingdom. In the vegetable kingdom it may be a normal event. The researches of Quatrefages have thrown no additional light whatever on the anatomy of this system, having mistaken the true utero-ovaria for lateral secreting pouches. Amid so little that was clear, and so much that was confused, it became obvious therefore that nothing less than independent and patient dissections would solve the enigma as to the mechanism of reproduction in this worm. The author trusts that he will be able to show that he has satisfactorily accomplished this object.

The first part of the reproductive system observed on opening the body along the dorsal median line, is the glandular white mass which embraces the œsophagus (as shown in Plate IX. fig. 66 *a*, *a*, in a pregnant individual). The component lobuli of this mass vary in size and number, according to the age of the specimen under inspection. They are tied down to the intersegmental partitions, and communicate (fig. 67 *a*, in an individual not pregnant) with minute ducts which run longitudinally on either side of the median line, from one end of the body to the other (fig. 66 *b*, *b*). When compressed they discharge a milky fluid, which is their proper secretion. It is true seminal fluid; it is not emitted directly externally, but into the longitudinal ducts (*b*, *b*, fig. 66 and *b*, *b*, fig. 67) through the excretory channels (*a*, *a*), which are common to the whole utero-ovarian system. From these longitudinal conduits the fertilizing fluid passes laterally along still minuter ducts (*b*, *b*, *b*, fig. 67, and *a*, fig. 68), which open directly into the utero-ovarian sacculus. In fig. 68 spermatic animalcules are represented in progress of passage from the longitudinal ducts into the lateral duct (*a*), which conveys them immediately into contact with the ova (*b*). This fact of the actual presence of sperm-cells in this duct of the female system dispels every obscurity with respect to the mechanism of self-impregnation, probably in all Annelida. In fig. 67 is represented the copulative pouches, so called because no other probable use can be assigned to them (*c*, *c*). They are unquestionably an integral part of the generative apparatus, though their functions may only be mechanical. In the Earth-worm they are concealed by the testicular masses. These latter organs in fig. 67 are removed in order to display the copulative pouches (*c*, *c*, *c*), which amount to four or six in number on either

* See last edition of Dr. Carpenter's Principles of Comparative Physiology, pp. 954 and 955.

side of the median line, and open externally by orifices (fig. 69), seen outside on the abdominal surface. They are simple cæcal vesicles, communicating with no detectable duct. It is not improbable, from the analogy of the intromittent organs, which will be subsequently shown to be contained within vesicles of a similar character in *Nais*, that they may lodge an intromittent instrument of some sort, though its presence has not yet been proved by actual observations. It is only on the supposition that some such organ is contained within these pouches that their mechanical functions can be understood. We are now prepared to enter upon a minuter description of the utero-ovarian organs. These marvellous organs are constructed in the Earth-worm with great exactitude on the model of those of the Leech. A tube (*a*, fig. 68) proceeding from the common testicular duct (*b*, *b*, fig. 66) runs along the upper part of the segmental dissepiment, which serves, as already explained, to convey the sperm-fluid into the uterine cavity. This tube is embraced, as at a', a'' (fig. 68), by stromatous tissue, which is densely charged with ova. These ova seem successively to be thrown into the channel of duct *a*, (fig. 68) where they are brought under the direct agency of the fertilizing fluid; thus fecundated they travel onwards in the line of the circumference of the ovarian uterus, b, b', b'', b''', undergoing greater and greater development, until finally in the passage *d*, terminating in the outlet d', they dehisce, and the young appear alive and active. After a sojourn of variable duration in this passage, the young escape externally through the outlet d', D. To the concavity of this organ a pouch or marsupium is appended. This part, during the breeding season, is crowded with ova on the point of giving escape to the young, c'. From this marsupium the ova descend as at b''', in a very advanced state of development. It may be designated the true uterine segment of the utero-ovarian organ, the place wherein the ova undergo the process of incubation, that in which the young are hatched. The *whole* of the interior (except the marsupium) of the ovario-uterine passages are lined with vibratile epithelium. The cilia are active and vigorous during the season of reproduction, but undistinguishable during the rest of the year. A comparison of this organ with that of the Leech will show that the so-called "respiratory sacculus" (Dugès) of the Leech is altogether absent in the Earth-worm. Considering the difference in the disposition of the male organs in the two species, the absence of this singular appendage in *Lumbricus* can excite no surprise. With this exception the reproductive systems of these two worms are formed on one and the same principle.

During the reproductive season, in the Earth-worm it is a matter of easy observation to trace the evolution of the ova throughout all its phases. It appears first (1, fig. 70) under the character of a minute, pellucid, nucleated, orbicular cell, of which the germinal vesicle and its contained germinal spot exceed very slightly in transparency the surrounding vitelline mass. The first appreciable departure from this unimpregnated type, which occurs in consequence of fertilization, consists in a thickening of the vitellus (2), by which, by contrast, the germinal vesicle is rendered much more distinct, the germinal spot at this stage being only obscurely perceptible.

Under the succeeding phase (3) the germinal spot presents itself under the character of a double-cell, surrounded by a pellucid zone, which is evidently still the germinal vesicle. At the next stage (4) the double-cell has multiplied into a series, arranged linearly and slightly curved to conform to the circumference of the vitelline membrane. This line of cells is still separated from the material of the yolk by a very transparent interval, definedly bounded, evidently by a membrane. This membrane must be the involucrum of the germinal vesicle.

The succeeding stage (5) is marked by a still further development of this *curved line of cells.* At a subsequent phase (6) these cells assume the unquestionable character of *young* worms having the power of independent motion while yet in the midst of vitelline mass. What is remarkable is, that the ovum, while the young is thus being evolved, undergoes a great increase of size. This can only occur by absorption of nutrient fluid from *without.*

At (b'''', fig. 68) the inferior uterine duct, it will be seen that the young escape out of the ova before they finally leave the parent, and that they are endowed with independent capability of locomotion ; 7, 8, 9, 10, fig. 71, illustrate the minute anatomy of the young at this stage (intra-uterine) of growth. Minute groups of molecules are first seen (7) in the axis of the body, which subsequently become fused (8) into a continuous series, in which it is impossible to discern a channel. At another age, however, a distinct intestinal canal (9) appears; this is surrounded on either side by a longitudinal row of cells which indicate the future blood-vessels. Still further developed (10), this canal exhibits incipient evidences of segmental contractions; and what should be expressly noted, the interval between the intestine and integument becomes filled with a fluid, already corpusculated, the motions of which may be distinctly and unmistakeably discerned. Thus the physiologist has attained to a knowledge of *one* definitive *fact* in relation to the embryological history of the chylo-aqueous fluid of the peritoneal cavity of the Annelida, that it begins its functions in the embryo *before* the true-blood. This latter is a system of subsequent development. So simple is the first stage of nutrition that it is accomplished exclusively by the chylo-peritoneal fluid. It may be here affirmed (what may hereafter prove to be embryologically true of all worms, and probably of all articulated animals) of the Earth-worm, that the younger the individual the greater the volume of the chylo-peritoneal fluid, the older the less; the proportion of this fluid, in other words, is inversely as the age. It is thus established by actual demonstration, that the Earth-worm is *viviparous*, and that it is hermaphrodite and self-impregnating, although only under the condition of being united to another individual.

Illustrations of the generative organs of *Nais filiformis* adorn the pages of almost every systematic work on comparative anatomy, published since the date of the researches of M. Dugès. Each author in long succession, as usual, adopts reverently the original of M. Dugès; where he is wrong they are wrong, where right they are so. The researches of M. Dugès into the anatomy of the generative system of this little worm constitute undoubtedly his master-performance in minute investigation. At the period of his inquiries it was by no means easy to unravel the reproductive organs of *Nais.* Itself of microscopic minuteness, it demands the use of the highest and the clearest powers, and that too in a living specimen, ceaselessly in motion, that the problem may be satisfactorily solved. The descriptions amount to a creditable approximation to the results obtained through aid of the best modern microscope *. They are notwithstanding deficient, in respect that they omit all allusion to parts which are indispensable to the sexual system as a whole.

A comparison of the familiar figures of Dugès with those which are published for the first time in connexion with this Memoir, will enable the phy-

* Nearly two months of my time were almost *exclusively* devoted to the study of the reproductive organs of *Nais filiformis.* During this period *thousands* of separate individuals were submitted to dissection. It was only in one, now and then, that those developed conditions of the sexual system could be found, which were essential to the success of the inquiry. There is, therefore, every excuse for inaccuracy.

siologist at once to perceive that the *whole* system is limited by M. Dugès to the glandular mass which is so readily observed about the anterior third of the body, whereas in reality this only constitutes *one segmental unit*, more developed only than those are repeated in every ring of the body. Moreover those singular intromittent organs lodged within pyriform vesicles, now first described, were wholly unknown to M. Dugès. Nor was this anatomist aware that in this worm the *ovipassages open* by means of a fimbriated, ciliated extremity freely into the cavity of the peritoneum.

Expounding the views of M. Dugès, Mr. Rymer Jones observes*, "The generative system of the *Nais* presents a somewhat different arrangement to that which exists in the Earth-worm. The swollen part of the body, in which the sexual organs are placed, occupies a space of from five or six rings, beginning at the eleventh. On each side of the eleventh segment is a minute transverse slit, communicating with a slightly flexuous canal, which terminates in a transparent pyriform pouch or vesicle; the latter contains a clear fluid, in which minute vermiform bodies are seen to float, and most probably represent the testis. The twelfth segment likewise exhibits two openings, each placed upon the centre of a little nipple; these are the orifices leading to the female portions of the sexual system. The ovaria are composed of four large, and several smaller masses of a granular character, and from them proceed long and tortuous oviducts, which just before their terminations at the lateral openings become thick and granular. These animals most likely copulate like the Earth-worms, and lay their eggs in a similar manner. We have already seen in *Lumbricus terrestris* ova containing two yolks, and consequently giving birth to two animals; but in the *Nais* every egg produces ten or twelve young ones; or perhaps we ought rather to say, that what appears to be a single egg is in fact merely a capsule enclosing distinct ova, from which a numerous progeny arises. The manner in which these compounds are formed is easily understood when we consider the structure of the oviduct described above. The granular germs escape no doubt separately from the ovaria, and remain distinct from each other, as they pass along the tortuous canal which leads to the external opening; but at length arriving at the thick and glandular portion of the oviferous tube, several of them become enclosed in a common investment secreted by the walls of the oviduct, and are expelled from the body with the outward appearance of a simple egg." This is the account of M. Dugès with reference to the reproductive organs of *Nais filiformis*.

The author of this Report will now proceed to state the results of his own examination, conducted at great cost of time and labour.

Every *Nais*, in relation to this system, is identically constituted; this worm therefore, like the preceding, is androgynous. *Every individual* towards the latter end of the summer dies by the bisection of the body. It is not true, as reported by Dugès, and before him by Spallanzani, that the fragments into which the body of each worm becomes resolved, is again reconstructed into a perfect whole. Although the sexual system exhibits a tendency to segmental repetition, there devolves upon the large anterior portion described by Dugès a special function, which the rest cannot perform; and, on the contrary, a duty falls on the posterior segmental units of the system which the anterior cannot discharge. It is consequently evident that neither of the moieties into which the body is resolved during the crisis of the reproductive season can be organically perfect. Such fragmentary organism is wanting in elements paramountly essential to individuality.

* *Op. cit.* p. 209.

In order to facilitate the comprehension of the succeeding description, it is proposed to enumerate the component parts of the sexual apparatus of *Nais* in the order of their position from before backwards.

The two pear-shaped sacculi (a, a, Plate VIII. fig. 72) are sufficiently prominent and defined in outline to be traced satisfactorily by the eye. The fundus of these sacculi exhibits no traceable orifice of communication with the glandular bodies (c, c, c', c') by which they are enveloped; it is quite certain, however, that this communication exists. The *interior* of these sacculi is *not* lined by vibratile epithelium; they lodge a peculiar, flexible, arrow-headed organ (b, b), which is often seen extruded through the orifice (a') to a considerable distance; this organ is an indisputable intromittent instrument. Its axis is hollow, and its root is structurally identified with the parietes of the vesicle in which it is contained. The large-celled glandular masses (c', c) are testicular, and contribute the fluid which is emitted by the penis (b') through the orifice (a') into the vulva (d), if not of the *same*, of another individual. No other parts than these masses (c', c), discoverable in *Nais*, are charged with sperm-cells, or, as Dr. Farre has designated them, ciliated corpuscles (m). These organs, therefore, are evidently the sole male apparatus of *Nais*; they furnish the secretion which, when introduced into the uteri (d'), fecundate the ova contained in the large masses (g). These last masses are ultimately composed of the elements (n), which consist of vitelline, nucleated, orbicular cells. Through a channel, not yet clearly defined, these ova find their way into the convoluted duct (f), which is prolonged from the fundus of the uterus (d), and terminates in a remarkable fimbriated extremity (e), through which the fertilized ova escape into the open cavity of the peritoneum. This singular organ, which may be divided into the uterine cavity, the fallopian duct, and *morsus diaboli*, is repeated in every segment, as seen at i, k, &c. In the posterior units, however, of this system the large ovarian masses (g) are not reproduced; they are peculiar to the first and most anterior of the system. In the posterior they are replaced by another description of stromatous tissue (as seen at j, j), which embraces the mid-portion of each duct. In the absence of any demonstrable male apparatus in connexion with these posterior utero-ovarian organs, there remains no alternative but to believe that the fimbriated extremities (k, k) *floating freely and loosely* in the fluid of the peritoneal cavity, and lined internally with active cilia, take up sperm-cells from the fluid of the peritoneal cavity, in which they may be seen suspended, conveying them through the duct until they reach that portion (j) which is embraced by the ovarian tissue. At this stage the ova from this tissue are detached into the duct, where they come into direct contact with the spermatic elements. The ova thus fertilized travel onwards under ciliary agency, for which these parts are quite remarkable, and finally escape at the outer orifice (i, i); they escape as ova. *Nais* is therefore an oviparous worm. Young worms are never found in any part of the body, nor at any time have true ova been seen in the fluid of the peritoneal cavity.

Nais is the only worm yet known in which the sexual organs communicate thus directly with the peritoneal cavity, and in which the fluid contents of this cavity enacts a mechanical part in propagating throughout the female elements of the reproductive system the fecundating fluid. It is not, however, the only Annelid in which the female moiety *only* of the sexual system is segmentally repeated. In the Earth-worm, the testicular masses were shown to be circumscribed to one region of the body, while the utero-ovaria were reproduced in every segment. The *Terebellæ* also exhibit the tendency to repetition only in the female elements of this system. The male glands

are grouped into a lobulated mass at the median line. The utero-ovaria occur as segmentally repeated sacculi, communicating on the ventral surface of the body by perceptible orifices. In *Terebella nebulosa* the whole of the sexual system may be readily demonstrated; it lies underneath the alimentary canal. To expose it to view this latter must therefore be removed. Along the median line is accumulated under the form of white lobulated masses the testicular glands. The secretion furnished by these masses is conveyed by means of a common duct to a receptacle, a sacculus, situated at its anterior extremity. This organ communicates externally by an orifice or two, through which the spermatic fluid is emitted. During the contact of two individuals, this fluid passes *outside* along the abdominal surface of the body, and thence finds its way into the ovario-uterine organs, which exist to the number of ten on either side of the abdominal median line, and which communicate by corresponding orifices externally.

The minute anatomy of these utero-ovarian organs in *Terebella nebulosa*, is well calculated to elucidate the mechanism of reproduction in several other species of Annelida.

Each lateral utriculus is divided longitudinally into two distinct compartments, of which one is thicker (in the parietes) at the attached end, and more vascular and redder in colour than the other, which is a mere membranous receptacle. A small glandular mass exists at the attached end of each of these organs, which during the reproductive season undergo a remarkable increase of size; they are true ova-producing bodies. From this stromatous structure the ova escape into *one* of the compartments of the utricle, where they fall under the influence of the spermatic fluid contained (received from without) in the other. They sojourn for some time in this receptacle, and finally escape as *ova*. The *Terebellæ* are therefore *oviparous*.

The sexual system of *Arenicola* is organized on a plan which intimately resembles that just described in *T. nebulosa*; there are, however, in this worm no median testicular masses. The male and female elements are attached to the lateral *sacculi*, which in this worm, like *T. nebulosa*, are arranged in lateral series, and divisible into two portions by a median partition. During the reproductive season these organs become highly vascular and prominent. The *Nereids* are constructed, as regards their reproductive system, very much on the type of that of *Lumbricus*. Each segment is furnished with its utero-ovarium. The *Phyllodoce* are organized on the same principle*.

Senses, Instinctive Actions, and Nervous System.

The nervous system of the Annelida is constructed in conformity with the articulated type. It is characterized essentially by the presence of a ganglion on the dorsal aspect of the œsophagus, and hence called the cephalic or supra-œsophageal; and another on the ventral surface of the œsophagus, known as the infra-œsophageal. These two ganglia are united by means of intermediate threads which descend on either side of the œsophagus, such as to embrace

* *Development of the Annelida.*—I have not yet attempted the study of the embryology of the *Annelida*; Milne-Edwards is the only observer who has contributed to this branch of comparative physiology. It is not likely to prove difficult of elucidation. From casual observations which I have instituted into this department of the subject of the Report, I do not think that it will prove very difficult of elucidation. I by no means agree with *Loven* in the accounts which he has given with reference to the metamorphoses of the Annelida. I have never yet seen an instance in which the embryo of an Annelid has departed from the true vermiform conformation. Appendages are successively developed during the progress of growth, as figured in the illustrations of Milne-Edwards, in the instance of *T. nebulosa*. Patience, truthfulness and exactitude are yet wanting to complete the department of the history of the British Annelida.

this tube in the enclosed span and forming the œsophageal ring. From the infraœsophageal ganglion the abdominal cord proceeds backward along the ventral median line. In some species this cord is double, in others single; in some it is nodulated at intervals, corresponding with the annuli of the body, and by ganglia; in others it seems to consist only of a continuous cord. When the former conformation prevails, the ganglia always bear reference in size and number to those of the segmental divisions of the body. Whatever may be the degree to which these ganglia are multiplied, they constitute only repetitions of one another. The cephalic ganglion, representing in situation and importance the brain of the higher Articulata, is distinguished from the rest. It originates nerves to the organs of sense. It is gifted, like a brain, with the distinctive power of directing, controlling and coordinating the movements of the entire body, whilst the influence of each ganglion of the trunk is confined only to its own segment. The longitudinal ganglionic cord occupies a position from which at first sight it may be inferred that it is not the homologon of the spinal cord of vertebrated animals. The spinal cord affects, in relation to the body, a *dorsal* situation, the ganglionic chain of the Articulata a *ventral*. This difference of locality has been supposed to be at variance with the doctrine of *the equivalence* of these several forms of nervous system. From the history of the development of articulate animals, however, it has been suggested that the whole body of these animals may be considered as in an inverted position; the part in which the segmentation is first distinguished in insects being the equivalent of the dorsal region of vertebrata, and that over which the germinal membrane is the last to close in, being homologous with the ventral region. Regarded under this aspect, the longitudinal nervous tract of Articulata corresponds with the spinal cord of vertebrated animals *in position*, as it will be afterwards seen that it does *in function*. We are indebted to Dr. Carpenter for an exact description of the ultimate structural characters of these ganglia:—"When the structure of the chain of ganglia is more particularly examined, it is found to consist of two distinct tracts; one of which is composed of nerve-*fibres* only, and passes backwards from the cephalic ganglion, over the surface of all the ganglia of the trunk, giving off branches to the nerves proceeding from them, while the other includes the *ganglia* themselves. Hence, as in the Mollusca, every part of the body has two sorts of nervous connexions; one with the cephalic ganglion, and the other with the ganglion of its own segment. Impressions made upon the afferent fibres, which proceed from any part of the body to the cephalic ganglia, harmonize and direct the general movements of the body, by means of the efferent nerves proceeding from them. For the purely reflex operations, on the other hand, the ganglia of the ventral cord are sufficient, each one ministering to the actions of its own segment, and to a certain extent also to those of the other segments. It has been ascertained by the careful dissections of Mr. Newport, to whom we owe all our most accurate knowledge of the structure of the nervous system in articulated animals, that of the fibres constituting the roots by which the nerves are implanted in the ganglia, some pass into the vesicular matter of the ganglion, and after coming into relation with its vesicular substance, pass out again on the same side; whilst a second set, after traversing the vesicular matter, pass out by the trunks proceeding from the opposite side of the same ganglion; and a third set run along the portion of the cord which connects the ganglia of different segments, and enter the nervous trunks that issue from them at a distance of one or more ganglia above or below. Thus it appears, that an impression conveyed by an afferent fibre of any ganglion, may excite a motion in the muscles of the same side of its own segment; or in those of

the opposite side; or in those of segments at a greater or less distance, according to the point at which the efferent fibres leave the cord." The degree of development exhibited by the nervous system in this class of animals, as in all others, bears a direct ratio to that of the muscular system, the distinctness of the organs of sense, and the complication of the pedal and tactile appendages. When these last are entirely wanting, the ventral cord exhibits no ganglia; when they are highly developed, these are completely and powerfully formed. This rule however is liable to exception, since the nervous systems of the Leech and the Earth-worm are more prominently ganglionic than that of the *Nereids*.

In the Leech the nervous system consists of a long series of minute ganglia joined by internuncial cords; these ganglia amount to about 24 in number. The anterior pair, or that immediately beneath the œsophagus, is larger than the rest, forming a minute heart-shaped mass, which is circled by a delicate nervous collar embracing the gullet, with two small nodules of neurine situated upon the dorsal aspect of the mouth. The diminutive bodies last mentioned constitute that portion of the nervous system most immediately connected with sensation; for while the nervous filaments given off from the abdominal ganglia are distributed to the muscular integuments of the body, the nerves which issue from the supraœsophageal pair supply the oral sucker where the organs of sense are situated. In all homogangliata, indeed, it is exclusively from this cephalic pair of ganglia that the nerves appropriated to the instruments of the senses are derived; the name of *brain* may therefore be aptly applied to this part, since it is the physiological correlate, if not the anatomical homologon of the cerebral mass of more highly organized beings. In consequence of the rudimentary character of these centres, the apparatus of sensation associated therewith must be proportionably rudimentary. The material machinery of an organ of sense can only be utilized by a corresponding amount of nervous influence, and where the latter exists the former is commonly present. In the *Hirudinæ*, as in other Annelida, distinct ocelli have indeed been described by several anatomists. Although characterized by the utmost simplicity of structure, they are stated nevertheless to present, in the degree of their development, a proportion corresponding to the condition of the cerebral centres with which they are in relation. The eyes of the Leech are eight or ten in number, and are easily detected by the assistance of a lens, under the form of a semicircular row of black points, situated above the mouth upon the sucking surface of the oral disc, a position evidently calculated to render them efficient agents in detecting the presence of food. The structure of these simple eyes, according to Prof. Müller, does not as yet present any apparatus of transparent lenses adapted to collect or concentrate the rays of light; but each ocellus or visual speck would seem to be merely expansions of the terminal extremity of a nerve derived immediately from the brain, spread out beneath a kind of cornea formed by a delicate and transparent cuticle; behind this is a layer of black pigment, to which the dark colour of each ocular point is due. These ocelli are detectable in nearly all Annelida in ultimate organization; in all instances, however, they fall under the description above presented. In the *Nemertinidæ* these organules are prominently visible, amounting to 12 or 16 in number. The *Nereids* are distinguished for the large size of the eyes, which stand in relief at the bases of the tentacles as two black spots. Those who have watched the habits of the *Nereids* will scarcely doubt that they are gifted with the power of discriminating external objects, of making towards some point, and of avoiding others. In the absence of such an optical arrangement as may be fitted to collect the rays of light, the physiologist, however, can form no con-

ception of the mechanism of light in these animals; if this endowment *really* is conferred upon *them*, under the conditions and in conformity with the laws which affect these organs in all the higher animals. It were however by no means irreconcileable with the views entertained at present as probable by many philosophers with reference to the properties of light, to suppose that this subtile agent may be rendered perceptible to the sensorium of the humblest animals, by means of a mechanism very different from that which anatomists and opticians recognize in the apparatus of an eye. It is not essential to the *practical purposes* of the lowest forms of life that the objects of the external world should be *seen*, that pictures of them should be painted upon the retina; it were enough that the mere presence or absence of an objective body should become evident to the sensations of the animal by the *positiveness* or negativeness of the impressions received. A refinedly exalted sense of touch, tactile sensibility, would suffice to accomplish this object. It is not easy for those who have never enjoyed the spectacle of the 'feat of touch,' performed by the tentaculated worms, to estimate adequately the extreme acuteness of the sensibility which resides at the extremities of the living and sagacious threads with which the head and sides of the body are garnished. They select, reject, move towards and recede from minute external objects with all the precision of microscopic animals gifted with the surest eagle-sight. The *necessity* therefore of *ordinary* organs of sight, in the present state of physical and physiological science, it is by no means essential to admit, while acknowledging that *under agency* and *stimulus* of light the humblest beings, though unendowed with normal visual organs, may yet steer themselves harmlessly, readily and unerringly through the thickly-tangled labyrinth of mud and stone and gravel and weed, amid the twilight of which the habitat of many of them may have been cast.

It is a remarkable fact in the history of the Annelida, that scarcely any *species*, however organized, whether furnished or not with external locomotive organs, in its numerous and varied muscular evolutions *ever moves directly backwards*. The movements consist always of serpentiform pranks, or those of elaborate coiling. It is by *the head* however that the movement is invariably *initiated*. The tail is always in the rear, never in the van. The animal never marches backwards. The head never delegates to the tail the authority of leading, directing or controlling the evolutions of the frame; not even in the *Clymenidæ*, in which the caudal ganglion exceeds the cephalic in dimensions. The power of retreat however, by exception, does exist in the tubicolous worms, and they are ingeniously provided with locomotive appendages by which the back-movement is performed with as much facility as the forward. These curious facts are well calculated to elucidate many points of great interest in the physiology of the nervous system of these annulose forms. The elaborate dissections of Mr. Newport have already proved beyond doubt that fibres of communication, from every part of the body of the articulated animal, converge upon, while others radiate from, the central cephalic ganglia. Through the intervention of such cords, these masses become the controllers of all the *consensual* muscular actions of the body. As Dr. Carpenter has argued with masterly clearness, *sensation, the rousing of consciousness*, is involved in such movements. Although excited by external impressions, they are *not* automatic—they are raised in character one degree above the purely automatic. Although stimulated by influences from without, the cephalic ganglia, unlike the abdominal, yet possess the power of subordinating and coordinating a complex succession of muscular evolutions with a view to the attainment of a definite end. *This is instinct!* This regulating power does not however reside, even in its lowest form, in the

abdominal ganglia. These last act unquestionably on a purely physical principle. Their agency is exclusively excito-motory. Each ganglion is limited in its influence to the annulus to which it belongs. The stimulus of external contact affecting the extremities of its afferent fibres determines the return force, the reaction, conveyed to the muscles through the medium of the efferent nerves. Though thus automatic in the principle of their action, the cephalic masses nevertheless exercise over the abdominal ganglia an *interfering* influence. The force of the former mingles with that of the latter with a view to its guidance and direction; muscular agency is thus moderated and governed. The automatic force originating in the abdominal ganglia confers on the muscles the *power* of contraction; the *sensational* or *instinctive* influence of the cephalic masses *directs* this blind power, such as that consensual harmony and coordination may result from the intricate evolutions.

The laborious researches of Mr. Newport on the Nervous System of the Myriapoda* apply with equal exactness to that of the Annelida. Expounding the views of Mr. Newport and announcing his results, Dr. Carpenter observes†, "The general conformation of the articulated animals and the arrangements of the parts of their nervous system render them peculiarly favourable subjects for the study of the *reflex* actions, some of the principal phænomena of which will now be described. The *Mantis religiosa* customarily places itself in a curious position, especially when threatened or attacked, resting upon its two posterior pair of legs and elevating its thorax with the anterior pair, which are armed with powerful claws. Now if the anterior segment of the thorax with its attached members be removed, the posterior part of the body will still remain balanced upon the four legs which belong to it, resisting any attempt to overthrow it, recovering its position when disturbed, and performing the same agitated movements of the wings and elytra as when the unmutilated insect is irritated; on the other hand, the detached portion of the thorax, which contains a ganglion, will, when separated from the head, set in motion its long arms and impress their hooks on the fingers which hold it. If the head of a *Centipede* be cut off whilst it is in motion, the body will continue to move onward by the action of the legs; and the same will take place in the separate parts if the body be divided into several distinct portions. After these actions have come to an end they may be exerted again by irritating any part of the nervous centres or the cut extremities of the nervous cord. The body is moved forwards by the regular and successive actions of the legs, as in the natural state; *but its movements are always forwards, never backwards*, and are only directed to one side when the forward movement is checked by an interposed obstacle. Hence, although they might *seem* to indicate consciousness and a guiding will, they do not so in reality, for they are carried on as it were mechanically, and show no direction of object, no avoidance of danger. If the body be opposed in its progress by an obstacle of not more than half of its own height, it mounts over it and moves directly onwards as in its natural state; but if the obstacle be equal to its own height, its progress is arrested, and cut extremities of the body remain forced up against the opposing substance, *the legs still continuing to move.* If, again, the nervous cord of a *Centipede* be divided in the middle of the trunk, so that the hinder legs are cut off from connexion with the cephalic ganglia, they will continue to move, but not in harmony with those of the fore-part of the body, being completely paralysed, so far as the animal's controlling power is concerned, though still capable of performing

* See Newport in the Philosophical Transactions for 1843.

† Principles of General and Comparative Physiology.

reflex movements by the influence of their own ganglia, which may thus continue to propel the body in opposition to the determinations of the animal itself. The case is still more remarkable when the nervous cord is not merely divided, but a portion of it is entirely removed from the middle of the trunk, for the anterior legs still remain obedient to the animal's control; the legs of the segments from which the nervous cord has been removed are altogether motionless, whilst those of the posterior segments continue to act, through the reflex power of their own ganglia, in a manner which shows that the animal has no power of checking or directing them."

Parallel experiments to the preceding, performed on any of the Annelida, lead invariably to corresponding results. From these and similar observations, the conclusion may be safely drawn that the ordinary movements of the locomotive appendages of annulose and articulated animals are *reflex* in character, and may take place under the exclusive agency of the *ganglia of the segments* to which they may be superadded, whilst in the perfect being these movements are harmonized, controlled and directed by impulses which act through the cephalic ganglia and the nerves proceeding from them. As formerly stated, the operations to which these latter ganglia are subservient are entirely of a consensual nature, being immediately prompted by sensations, chiefly those of sight and hunger, and never by any processes of a truly rational character. The habits of the Annelida, however attentively watched, suggest irresistibly the inference, that, although evidently directed to the attainment of certain ends, they are very far from being of the same spontaneous nature, far from indicating the same *designed* adaptation of means to ends, as those of the higher and more intelligent animals. The actions of these little humble beings are uniform and unvarying, for ever repetitions—the different individuals of the same species executing precisely the same movements when the circumstances are the same—and by the very elaborate nature of the mental operations which would be required, in many instances, to arrive at the same results by an effort of reason. The *Sabellæ* in the construction of their tubes repeat the same invariable 'round' of actions; they obey an impulsive principle which discovers no change of plan. The *Terebellæ* gather the shell-fragments for the manufacture of *their* tubes on principles of the same monotonous uniformity. The *Sand-lug* undermines the strand, generation after generation, with exact and undeviating regularity. Though governed only by the unreasoning impulses of instinct, these little worms yet construct for themselves habitations, which, in elegance of arrangement or appropriateness of structure, the most enlightened human intelligence, working on the most refined geometrical principles, could not surpass.

It is not easy to express the pleasure which is excited in the mind of the observer of nature while contemplating the habits and manners of the Annelida. Every movement exemplifies the curve of beauty; every tentacle winds ceaselessly and rapidly through a thousand forms of matchless grace. Whether coiling round a visible object, or picking up a microscopic molecule for the construction of the cell, it exhibits a delicacy and precision of aim which the erudite finger of the most skilful artisan never equalled. The refined perfection of its muscular performances is matched only by its exquisite sensibility. Like the human hand, of which the manifold endowments have exhausted the admiring eloquence of philosophers and theologians, it unites in its little self the most varied capacities. It is at once an eye, an ear, a nose and a finger; it sees, it hears, it smells, it touches! Leading for the most part a subaqueous or subterranean life, the sense of sight in the Annelid is little required; and gifted in every part of the body with a superlative

tenderness of touch, the sense of hearing is rendered unnecessary. Anatomy accordingly demonstrates only the obscurest rudiments of an organ of vision, while that of hearing has eluded the scrutiny of the minutest examination. Is it not to be marvelled at that these humble beings should see without eyes, hear without ears, and smell without a nose? It is not affirmed that this is literally and entirely true, but it is exact to a degree enough to prove the wondrous manner in which the sense of touch is made to supersede all the other senses.

Whether progressing on the solid surface, or moving through water, or tunneling the sand, advancing or retreating in its tube, the Annelid performs muscular feats distinguished at once for their complexity and harmony. In grace of coil the little worm excels the serpent. In regularity of march the thousand-footed Nereid out-rivals the Centipede. The leaf-armed Phyllodoce swims with greater beauty of mechanism than the fish, and the vulgar earth-worm shames the mole in the exactitude and skill of its subterranean operations. Why then should "the humble worm" have remained so long without a historian? Is the care, the wisdom, the love, the paternal solicitude of the Almighty not legible in the surpassing organism, the ingenious architectures, the individual and social habits, the adaptation of structure to the physical conditions of existence of these "degraded" beings? Do not their habitations display His care, their instincts His wisdom, their *merriment* His love, their vast specific diversities His solicitous and inscrutable Providence?

Second Report on the Facts of Earthquake Phænomena. *By* ROBERT MALLET, *C.E., M.R.I.A.*

In my previous Report upon the Facts of Earthquake Phænomena, printed in the Transactions of the British Association for 1850, I stated in conclusion my hope, with the permission of the Association, to supply in a second report answers to five desiderata which I named.

The present is an endeavour to fulfill this with respect to four out of these five, which were—

1st. A complete catalogue or chronology of earthquakes from the earliest times to the present day, discussed with reference to time and to distribution over the earth's surface.

2nd. Earthquake maps founded upon this discussion.

3rd. As complete a bibliography of earthquake literature as might be collected.

4th. An account of my own experimental admeasurements now (1850) in progress, of the rate of earthquake-wave transit, through some of the rocky and incoherent formations of the earth's surface.

5th. An account of the progress made in the construction of a self-registering seismometer, with the aid of the British Association.

It will be most convenient to proceed with the fourth desideratum in the above list first.

The views promulgated by me in 1846 (Trans. R.I. Acad.), in which for the first time I sought to connect into a systematic whole, the three grand classes of phænomena, of which (more or less varied) every earthquake consists, and to frame them into a consistent theory, upon the basis that "an earthquake is

the transit through the earth's crust of a wave of elastic compression," though received at first with some hesitation, perhaps with doubt, appear rapidly to have claimed the general assent that verisimilitude warranted, and indeed now have been admitted as a portion of our systematic knowledge in the works of Somerville, De la Beche, Lyell, and others. It always however appeared desirable to me that the truth should be submitted to an "experimentum crucis," and in the original paper above noticed, as also in the 'Admiralty Manual,' I proposed, as an important object to physical experimentalists, to determine the actual rate and other conditions of propagation of elastic waves or pulses through the various formations of the earth's crust when artificially produced by the explosion of gunpowder, to be fired at known distances from the points of observation by means of the galvanic battery, the time of wave transit to be noted.

The subject not having been taken up by others, doubtless, amongst other reasons, because few competent experimenters are found in circumstances of locality suited for such experiments, or can command the time and personal labour demanded for conducting them, not to speak of the large expenditure in money which such operations require, I undertook the task, and with the able and zealous assistance of my eldest son, William Mallet, whose help, efficient beyond the promise of his years, I acknowledge, with I trust a pardonable pride, have been enabled to complete it during the summers and autumns of the years 1849–50.

The precise object, then, that I set before me was to measure the transit rate of pulses in two different media, such as might be considered to give the extreme *limits of speed*, viz. the fastest and the slowest, likely to be found in any of the formations occupying considerable tracts of the earth's crust.

It would doubtless be found that the limits of *wave slowness* should occur in some discontinuous medium, and in this the most rapid extinction of impulse would also occur. Preliminary knowledge already pointed out solid granite or other crystalline rock as the medium giving the limits of *wave fastness*, and that in what the impulse would be transferred furthest.

It fortunately happened that both these media could be commanded at the distance of a few miles from Dublin, at a point of the coast easily accessible by railway, and offering the requisite conditions of uniformity of medium over a sufficient range and depth for experiment,—nearly level surface for admeasurement of the ranges, and a locality such that the required explosions could be made free from danger to other persons and without interruption.

Killiney Bay, on the coast of the County of Dublin, offered, along its widely extended beach, a mass of *wet sand* admirably circumstanced and suited for one limit, while the granite of Dalkey Island, closely adjacent and not half a mile from the shore, about a mile northward, gave as a medium the other limit of wave transit which is not likely to be exceeded by at least any European formation.

The map (Plate XII.) shows the positions finally chosen for both sets of experiments, the directions and lengths of the two measured ranges being indicated by dark lines: AB, the Killiney Bay range in sand; CD, the Dalkey Island range in granite.

The sites being determined, I made application to the commanding officers of Engineers, and to those of the Coast Guard, to obtain the assistance of the non-commissioned officers and men of both services, stationed in the several batteries along the line of adjacent coast, and for permission to use one or more of the batteries as places of deposit for our instruments; and I have to acknowledge the prompt and cordial manner in which my requests

were acceded to, and the efficient assistance that was rendered us by the extremely intelligent men both of the Artillery and Coast Guard services whose cooperation we obtained.

I now proceed to describe the operations and instruments used in the experiments as to the

Rate of Wave-transit in the Killiney Bay Sand.

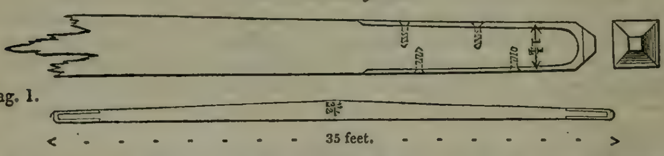
The site for this class of experiments was chosen on the shore of Killiney Bay, where a straight and almost perfectly level range of strand, consisting wholly of deep and *dead* sand, of particles, chiefly of quartz, from the size of small pins' heads to large mustard seed, resting on a deep bed of hard clay and gravel, is found stretching along more than five miles of shore, free from all rock *in situ*, and with but very few small-sized granite boulders at one or two spots imbedded in the sand.

The sand contains from 80 to 90 per cent. of white and yellow quartz, about 6 or 8 per cent. of gray and green slate, 3 or 4 per cent. of black argillaceous limestone, effervescing with acids, all in grains, and occasional fragments of felspar, schorl, and mica. The specific gravity of the whole taken in water is 2·481. A cubic foot of its solid materials would therefore weigh 155·06 lbs. avoir. A cubic foot of the moist sand was ascertained by experiment to weigh, when compressed to about the same extent as it is found on the strand, 111·05 lbs. The degree of porosity, or the amount of interstitial space in the sand to its solid material in a given bulk, is in the ratio of 44·01 : 111·05, or very nearly as 1 : 2·5.

Measuring the Base.—On the 18th of July, 1849, a range of a statute mile =5280 feet, was roughly marked out, staked and chained over by myself, William Mallet and Prof. Downing, T.C.D., who kindly assisted us in the measurement. Two accurately made fir-wood measuring-rods were prepared, each of $2\frac{1}{2}$ inches square in the middle, lessening to $1\frac{1}{4}$ inch at each end, and of 35 feet in length, shod with brass at both ends, which tapered to $\frac{1}{2}$ inch square (see Diag. 1.). These were accurately adjusted by a brass two-foot

Terminations of Rod.

Diag. 1.



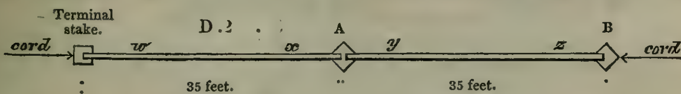
standard, made by Troughton, in the possession of Mr. George Yeates of Dublin, mathematical instrument maker, and said to be a copy of the old Exchequer standard, which he lent for the purpose. The final adjustments were made by a micrometer, dividing on the varnished face of the wood and on the straight side, both the rods lying parallel on a bench prepared to support them level and straight. The adjustment was compared on the day of measurement and found correct. The wood was straight-grained yellow pine-fir, quite dry and seasoned.

The mile to be measured accurately, having been now exactly ranged out by the theodolite and pegged in line, a heavy oak stake of 6 inches square was driven down 4 feet into the sand, at the northern extremity of the range (just under the battery, No. 7, Killiney Bay), and a brass composition nail was driven into the centre of the head of the stake when level with the surface of the sand.

A cord of about 250 yards in length was now stretched by hand from this

point, precisely in the range with the first peg or ranging-rod, and let to lie on the surface. One of the 35-foot rods was now laid down upon the level sand along the line (which the cord served accurately to mark), the extremity of the rod being over the centre of the brass nail in the stake head. Three pieces of deal board of 12 inches square each and $\frac{3}{4}$ inch thick, were provided, and one of these was placed flat on the sand with its centre under the other extremity of the 35-foot rod.

The other rod was now placed along the cord in line with the former, one of its extremities being laid within an inch or so of that of the former rod, and the other upon a similar piece of board (see Diag. 2). One person



(Downing) stooping, now brought the ends of the two rods gently together and into contact upon the board A.

Another person (the writer) observed that the extremity of the second rod upon the board B was not deranged or brought out of line in doing this, and that it was not shifted until the first rod had been again applied to it in advance.

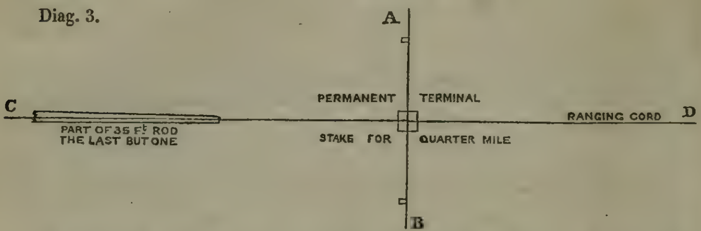
As soon as the visual contact was made at A, Downing gave the word (lift), and two gunners, placed at the positions *w*, *x*, lifted the first rod parallel to itself, carried it forward, and deposited it in advance with its rearward extremity again on the board B, and within an inch or so of the second rod; the other end being laid down on the third board (C), which was carried forward by another assistant in readiness, and who ran back for the board A as soon as he had deposited C. Downing now again brought the rods' ends into visual contact and gave the word (lift), when the rear rod was lifted and carried forward by two other gunners placed at *y* and *z*; and thus the measurement proceeded, the rods being alternately carried forward and their extremities brought into contact as described, guided in range by the cord and stakes, the cord itself being strained afresh when its end was nearly reached.

A third assistant (William Mallet) kept account of the number of applications of the rods, or rods' lengths, as a check upon the counting of Downing and myself. The rate of progress thus made was extremely rapid, nearly if not quite as fast, when the men became accustomed to it, as common chain measurement, and its accuracy seemed very great.

As there are $\frac{5280}{4}=1320$ feet in a quarter of a mile, and $\frac{1320}{35}=37+25$ feet, there were only 38 permutations to reach a quarter of a mile. As soon as the 38th rod was laid down and brought into contact it was "let lie," and then from its rearward extremity, 25 feet was counted off along the rod, and a fine string was passed across the 25 foot-mark, at right angles to the rod, reaching about 6 feet each way; a stake was driven temporarily in at each end of this to fix the string; the string loosed and the 35-foot rod removed, and the string again replaced. The intersection of this string, A, B, with the ranging cord, C, D, gave then the exact spot of the termination of the first quarter-mile (see Diag. 3). Both the cords were now laid aside, and the permanent 6-inch square oak terminal stake driven 4 feet to a level with the sand. The ranging cord and transverse string were now replaced, and at their point of intersection over the stake-head a brass composition nail was driven into the oak, which marked the precise termination of the first quarter-mile. The measurement then of the second quarter-mile proceeded in the

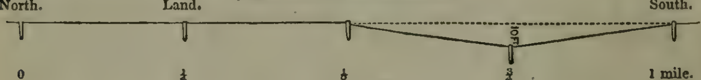
same manner, and so on to the end of the statute mile, marking each quarter-mile as before, and also the extremity of the mile, by oak 6-inch stakes and brass nails.

Diag. 3.



This work was done on the 18th and 19th of July, 1849. The only difficulty experienced was in crossing the Shanganah River at its mouth; here the 35-foot rods had to be carried over the water on stakes temporarily driven in, the several parties operating wading in the water, and a possible error of perhaps two inches may have occurred here; but from the checking of this operation over the rest of the line with the steel chain, and with the same operation repeated over parts of the line with the rods, I believe the whole mile to be measured correctly within an error of 4 or 5 inches at most. The first half-mile, going from north to south, is almost perfectly level; in the next quarter-mile the surface of the sand descends with almost perfect uniformity from about the level of high water to that of low water of ordinary tides, say nearly 10 feet, and again as gradually rises up to the extremity of the mile at the south. This arose from the base line being a chord to the curved line of beach of the bay. As the measurement was made along the *surface* of the sand all the way, except crossing Shanganagh River, an allowance must be made for this dip and rise again.

Section of Mile measured.



This, when calculated, gives a difference between the line measured along the surface of the sand and the true straight line carried through from end to end, of rather less than 1½ inch.

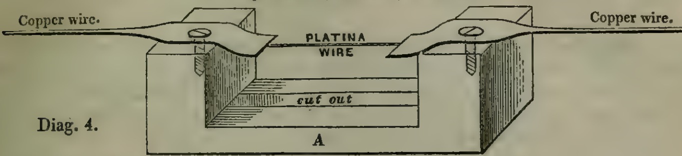
Subsequent remarks will show that this part of the base line became wholly unimportant to the experiments.

The preparation of the several instruments and materials, with some inevitable delays, occupied the time between this and the 25th of October, 1849, when, all being complete and the powder, with the galvanic batteries for firing deposited at the tower No. 9 and battery No. 7, a set of preliminary experiments was made to ascertain what quantity of powder it would be necessary to explode in order to render the pulse perceptible by the seismoscope at the distance of a mile.

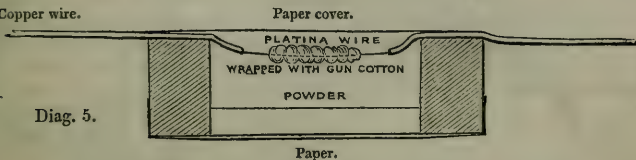
To this end twelve canisters of tin plate were made, each of which contained two pounds of powder, with room for the priming powder and wires, &c. These canisters were cylinders of about 8 inches long by 4 inches diameter, with an opening of 1½ inch diameter at each end, prepared with a neck to be closed by a bung-cork. The primings were made of wood; a copper

wire, diameter 16 Birmingham wire-gauge, flattened and screwed to each side; a fine platina wire streched between and soldered to both; the diameter of the platina wire that answered best was found to be such that 2 inches of

Priming Cartridges, nearly half size.



Diag. 4.



Diag. 5.

Longitudinal section.

it weighed 1·62 grain =0·01475, or nearly $\frac{1}{68}$th of an inch diameter, larger wire requiring too much time and energy of battery to heat properly, and a finer wire *losing* heat so rapidly by conduction as to be uncertain of firing the powder.

Taking the hint from this fact, it was found that the ignition was both made certain and quickened by wrapping the wire round with gun-cotton, whose bad conducting property and low temperature of ignition make it valuable in the galvanic priming for common powder. This being done, the hollow of the wood frame A was filled with fine glazed rifle powder, well-dried, and then a piece of fine thin paper was pasted round over all. This priming cartridge being inserted through the apertures in the ends of the canisters, the copper wires extending out at each end, a perforated bung-cork was slipped over one wire and secured in the neck of the canister, which was then filled up with Dartford blasting powder; the other bung was then inserted. The two wires outside, each about 5 feet long, were now wrapped round spirally with calico dipped in lac varnish, to insulate them; and finally, the bung-corks at each end were dipped into or coated with resinous cement, so as to make the whole canister water-tight. The wires being then coiled loosely up, they were complete.

I was indebted to Mr. Bergin of the Dublin and Kingstown Railway, for the use of his powerful and convenient modification of Davison's galvanic battery*, of which I had two troughs, consisting of six double cells each, of cast iron and zinc elements.

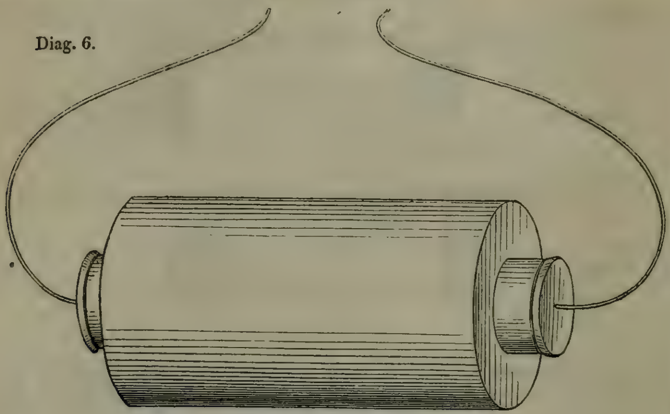
The cast-iron plates were immersed in strong commercial nitric acid mixed with commercial sulphuric acid and placed in porous earthen troughs, and opposed on each side by a zinc plate immersed outside the porous troughs in commercial sulphuric acid diluted with water. The surface in action, when this battery was in train, was for both sides of each cast-iron plate 168·75 square inches, and for the two opposed zinc surfaces 84·37 square inches in each element. It is unnecessary to enter into details here as to the very convenient arrangements for uniting and disconnecting the plates.

The igniting or deflagrating powers of this form of battery are enormous;

* See Lieut. Hutchinson's Mem. Prof. Pap. Roy. Eng., vol. vii.

with 12 cells in action, a solid copper wire of nearly a quarter of an inch in diameter could be almost instantly soldered on to a shilling laid on one of the binding screws of the opposite terminal plate. The exciting fluids, as actually used, will be stated hereafter.

Diag. 6.



Canister complete.

It will now be convenient to describe the instrument which I had constructed for the purpose of rendering visible to the eye the very feeblest impulses or shocks, when communicated from the shaken ground to the instrument.

The original idea of this instrument, which I have named the Seismoscope, and to whose sensibility much of the success of these experiments is due, suggested itself to me from observing the facility with which the image of a fixed star was obliterated when reflected from the surface of still water by the slightest disturbance of the fluid; and I at first proposed to observe through a telescope the image of the flame of a candle reflected at an incident angle of 45° from a trough of mercury, and take the moment of its disturbance from the disappearance of the flame. On communicating this however to my friend Dr. Robinson, Astronomer Royal, Armagh, who has throughout taken a lively interest in these experiments, and to whom I am indebted for many valuable suggestions and aid in the discussion of our results, he proposed to substitute for the candle-flame the image of a pair of cross wires placed in the focus of an achromatic object-glass, incident at 45° on the mercury, and received by another achromatic telescope at an equal angle, provided with one or two crossed wires intersecting the image of the former, and to note the *total disappearance* of the former at the moment of impulse.

The importance of this improvement was evident, and the instrument was constructed accordingly.

The Seismoscope (Pl. XIII. fig. 3) consists of a cast-iron base plate, *a a*, of 20 inches in length and 8 inches in width, and $\frac{1}{2}$ an inch in thickness; on the centre of the surface of which is placed a cast-iron rectangular trough, *b*, of 12 inches long, 4 inches wide, and 2 inches in depth, accurately planed and brought true in all its surfaces, and black varnished externally. At either end of this trough a brass vertical sliding pillar is screwed in, one of which carries a tube, *c*, provided with an achromatic object-glass at its lower

end, and a pair of cross wires at its focus. The other carries a small achromatic telescope, *d*, of the same aperture and provided with one vertical wire. Both tube and telescope are jointed so as to admit of motion in the vertical angle, and by means of the sliding pillars and screw-collars on them, can either be rotated round the axis of the pillars or moved up and down parallel therewith.

When the cast-iron trough is filled to the depth of 1 inch with clean mercury, and the perforated blackened tin cover, *e*, *e*, shown in dotted lines, laid on it, which excludes all light except what can reach the surface of mercury through the tube or telescope, and when the latter are placed in the same plane, and at angles of 45° to the surface of the mercury =90° to each other; then, while the cast-iron base plate and trough are perfectly still, the image of the cross wires of the tube are seen steadily reflected in the surface of the mercurial mirror, and intersected by the vertical wire of the telescope; but the slightest movement communicated to the whole instrument, or to any part of it, causes this image either to flicker or to disappear wholly for the moment.

In daylight the image is produced of course by the light of the sun; but as it was thought possible that these experiments would require to be conducted during the silence and quiet of night, a lamp, *k*, sliding upon a moveable iron rod, was added; parallel rays, transmitted through a screen of oiled parchment from this lamp, were adapted to pass into the tube, *c*. This part of the arrangement also was suggested by Dr. Robinson, but we never found night observations requisite.

As the movement or disappearance of the image is caused by the momentary passage of a small wave across the face of the otherwise undisturbed mercury, and as the front and rear slopes of this wave in their passage across the field act as the surfaces of a mirror whose angles of inclination to the line of collimation of the cross-wire tube are variable, so, the angles of incidence and reflexion being always equal, any deviation produced is doubled when seen in the axis of the collimating telescope.

This telescope has a focal length of 7·40 inches. If F=this focal length, V=the distance of distinct vision=(for R. Mallet) 12 inches, and M=the magnifying power of the telescope, then

$$M \times \frac{V}{F} = \text{the magnifying of an object seen in the apparatus,}$$

or

$$7 \times \frac{12}{7{\cdot}4} = \frac{84}{7{\cdot}4} = 11{\cdot}39.$$

Hence the total power of the instrument to magnify any small disturbance and make it apparent is $2 \times 11{\cdot}39 = 22{\cdot}78$, or nearly 23 times.

Its actual sensibility is very great, such, that resting upon solid granite rock, a blow of a light hammer on the rock can be perceived at 100 yards off; a stamp with the foot at 50 or 60 yards, and on compact sand or clay, a horse trotting can be observed at a quarter of a mile away. In towns the motion of the most solid buildings or of the ground is so continual that it is not possible anywhere to see the cross wires at all.

As the transit of any elastic wave or pulse is rendered evident by this instrument, in virtue of the production and transit of a small fluid wave through the mercury of the trough and along its surface (a small wave of translation), and as this wave is observed at the moment of its transit across the middle point of the trough, which is intersected by the optic axes of the two telescopes, and as the time occupied by the raising and transmitting of this

mercurial wave requires to be known, in order that the one half of the time of production and transit may become a constant, which will enter into the result of every observation made with the instrument, it was necessary rigidly to determine this time.

It was conceived, in the first instance, that as the length of the trough was in direction with the line of transit of the elastic wave producing the disturbance, the mercurial wave would be produced by the stroke of the *end* of the trough against the mercury, and that the time of mercurial wave production and transit might be obtained by providing another much longer trough of precisely equal transverse section and equal depth of mercury, and whose length should be a given multiple, say 10 times that of the trough of the seismoscope. Then by producing a longitudinally traversing wave of translation in this trough, by means of a wood plunger at one end, or of a blow, and observing how many times in 60″ this wave traversed the length of the trough, the time of the wave in the seismoscope trough could be got by the following formula:—

Let the length of the shorter canal or trough .... $= 1$.
That of the longer a multiple of it........................... $= n$.
The *whole* time of transit of the wave in the shorter trough, *i.e.* the time both of production and transit .... $= \mathrm{T}$.
The true time of transit *only* .... $= t$.
The *whole* time of transit in the longer trough .... $= t'$.

Then

$$t'-\mathrm{T}=(n-1)t,$$

and

$$t=\frac{t'-\mathrm{T}}{n-1}.$$

Therefore, if $\mathrm{R}=$the time of producing the wave,

$$\mathrm{T}-t=\mathrm{R}.$$

On trial, however, it was at once found that the effect of a blow, either on any part of the seismoscope or upon any support thereof, in whatever direction, was to produce not a mere longitudinal wave only, but a combination of waves emanating at the same moment from all sides of the trough, and again receding towards them, and so coming to rest, that in fact all sides of the trough vibrated and transmitted the vibration.

After several other methods had been attempted, it was found that upon placing the instrument upon a perfectly firm and immoveable base, such as the solid rock, and on gently tapping the latter with a rod of iron or metal while observing the cross wires, it was possible so to time the recurrence of the blows, that a recurrent disturbance could be kept up, so as just to keep the cross wires out of view.

If the number of blows in a minute was reduced one or two beats, the cross wires reappeared at certain determinate intervals; and if the number of blows was increased, they remained invisible, except at certain intervals (or beats), until the increased number became a multiple of that number which completely kept them out of view.

It was therefore obvious, that by ascertaining this number correctly by repeated observations, the number of pulses, divided into the time=60″, would give *twice* the time of producing and transmitting the wave in the mercurial trough, viz. the time of its production and advance, and recession and extinction, and that half this again would be the time of $\frac{1}{2}$ transit sought.

Accordingly a great number of such observations were made with the in-

strument resting on solid granite, the temperature of the mercury and instrument being 64° Fahr. The following gives some of the results, being one set of observations:—

No. of Experiments.	Cross wires observed by		
1.	230	beats in 60″.	
2.	230	,,	
3.	231 −	,,	
4.	231 −	,,	
5.	229 +	,,	
6.	230	,,	
7.	230	,,	
8.	228 +	,,	bad observation.
9.	229 +	,,	
10.	231 −	,,	

From this it may be concluded that 230 beats per minute just keep the cross wires out of view. The time of wave production and transit then is half this, or

$$\frac{60''}{230\times2}=\frac{60''}{460}=0{\cdot}13 \text{ of one second};$$

but as the image of the cross wires is reflected from the centre of the trough or from a point half way of its length or breadth, one half of the foregoing is the constant of correction due to wave-transit of the seismoscope, or

$$\frac{0{\cdot}13''}{2}=0{\cdot}065'' \text{ in time};$$

and as this will, in every observation with the seismoscope, appear to *delay* the arrival of the earth-wave at the instrument, this time converted into distance must be *added* to the rate of earth-wave transit otherwise obtained.

We now return to the preliminary trials as to the charge of powder required for each mine in the sand.

Twelve of the two-pound tin plate cartridges, before described, and one of Mr. Bergin's large batteries of six cells being prepared, (of which, however, only two cells were found requisite to fire the powder,) on the 25th of October 1849, the seismoscope was adjusted at the terminal north stake, and a cartridge was buried 4 feet in the sand, at the distance of half a mile, keeping it about 60 yards clear of the half-mile stake (to right or left), and fired. The two pounds of powder exploded, but was unable to *lift out* any sand at that depth, or to produce a shock sensible at the distance of half a mile. A second cartridge was buried 3 feet and fired; it blew out a column of sand, but no pulse was perceptible at the seismoscope, nor was any sound heard there through the air. A third cartridge was then buried 3 feet at a quarter of a mile distance from the seismoscope, but no pulse was perceptible on several repetitions. At one furlong therefore from the instrument another was buried 3 feet and fired; this was found on repetition to be distinctly perceptible by the seismoscope, causing the cross wires to disappear in the most distinct manner.

A rough approximation was thus made as to the quantity of powder required; for as the intensity of the pulse will vary, with the same original impulse, nearly as the square of the distance inversely, so it may be inferred, that to produce equal pulses at variable distances, the original impulse must vary in the same ratio; and taking the impulse of fired powder to be directly as its weight, if 2 lbs. produced a wave visible with the seismoscope, at $\frac{1}{8}$th of a mile it would require $(8)^2\times2$ to produce one equally visible at a mile, or 128 lbs.

Hence the quantity of powder was found to be so large that I determined to abandon my original intention of experimenting at a mile range, and to limit myself to half a mile, and for this chose the best half of the range, viz. the northern half mile, which was quite level and free from any error as to measurement, being all to the north of Shanganah River.

I also concluded that less than $(4)^2 \times 2$ lbs.$=32$ lbs. of powder would probably do, as the impulse given to the seismoscope by the 2 lbs. at a furlong range was more powerful than requisite for distinct observations. Subsequent trial on the 29th of October, 1849, proved this to be correct, and that 25 lbs. of powder gave an impulse distinctly visible at half-mile range*.

* It is of some importance to refer to the effects in concussion of the earth and air that have been occasionally observed to result from the explosion of known quantities of powder at determinate distances, because we thus get some measure (though a very inadequate one) of the amount of explosive or elastic force that must be concerned in the production of such concussive movements of the ground and of such subterranean noises, or sounds conveyed thence through the air, as have been actually noted by earthquake narrators.

The slight shocks frequently observed at Dublin by Professor Lloyd, and only capable of observation through the refined instruments of the magnetic observatory, as well as those so long and so continuously experienced at places such as Comrie in Perthshire, East Haddam in Connecticut, and Bale in Switzerland, are probably not due to true explosive efforts beneath, but rather to successive fracturing of beds of rock under the slow and gradual process of elevation or of depression, taking place either immediately beneath or perhaps at a considerable distance away; but our present experiments show how comparatively insignificant an explosive origin may be sufficient to transmit an instrumentally appreciable shock to a considerable distance.

I have referred in the Transactions of the Royal Irish Academy, vol. xxi., to the undulation of the ground, felt for several miles, when the large powder magazine was blown up in Sir John Moore's retreat to Corunna. Sir Christopher Wren demolished the great centre tower of old St. Paul's by a small mine of only 18 pounds weight of powder buried beneath one of the angles. The explosion, he informs us, lifted bodily through some inches above 3000 tons of masonry, and "the fall of so great a weight from a height of 200 feet gave a concussion to the ground that the inhabitants round about took for an earthquake."—*Wren's Parentalia*, pp. 283, 285.

When the great chalk cliff at Seaford was thrown down by the explosion of nearly 26,000 lbs. of powder (Sept. 1850), it is stated, "The rumbling noise was probably not heard half a mile off. Those who were in boats a little way out from the cliff state that they felt a slight shock. It was much stronger on the top of the cliff; persons standing there felt staggered by the shaking of the ground, and one of the batteries (galvanic) was thrown down by it."

"In Seaford, three quarters of a mile off, glasses upon the table were shaken, and one chimney fell. At New Haven, a distance of three miles, the shock was sensibly felt; about 300,000 tons of chalk was said to be an approximation to the weight moved."—*Times*, Sept. 1850.

When the late fatal explosion occurred at Hounslow Powder Mills, the following circumstances are narrated.

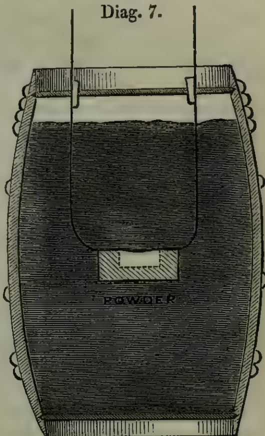
"A correspondent at Brighton informs us that the late fatal explosion at Hounslow was distinctly felt and heard at Sussex, a distance from Hounslow of between 50 and 60 miles. At Petworth, upwards of 40 miles off, three reports were distinctly heard, and a corresponding number of shocks were felt, so that the inhabitants ran out of their houses, imagining that they had felt shocks of an earthquake. Mr. Heslop, a teacher of languages, while walking near the mansion of Sir Isaac Lyon Goldsmid, at Hove, near Brighton, heard a noise as of distant thunder, but as the sky was clear he imagined that he must have heard a roar of artillery. It was then 25 minutes to 4 by his watch. Mr. Smith, a gardener and nurseryman, at the north part of Brighton, also distinctly heard the noise. The most conclusive evidence, however, that the explosion was felt between 50 and 60 miles from the spot is furnished by the following paragraph, copied from the *Sussex Advertiser* of Tuesday, a paper which was printed and in town before the news of the explosion reached Lewes:—'Accounts have reached this office from several persons, living in different parts of Lewes, who depose to having experienced a slight shock, as if of an earthquake, at about 20 minutes to 4 o'clock on Monday afternoon. There was no train passing through the tunnel at that hour. Moreover, the shock was felt in parts of the town not affected by the passage of trains. All the persons alluded to experienced the shock at the same period of time.' From various other places there are similar accounts, all agreeing as to time, but varying a little in

Nine casks of powder were fired in all; and this may be as convenient a place as any other to describe the arrangements made for their ignition, &c. Each cask held 25 lbs. weight of best Dartford, highly-glazed, coarse-grained commercial blasting powder, and was prepared for firing in the following way. The head of each cask was taken out by knocking off the hoops at one end. Two holes were bored through the head at 4 inches apart, each hole half an inch in diameter. Priming cartridges were made as already described for the tin plate cartridges, but with longer wires.

The ends of the two wires (which were brought parallel to each other at a distance of 4 inches) were passed up throug hh e holes in the loose head of the cask, until the priming cartridge was a foot or so below the head-piece; half the powder having been emptied out of the cask, the priming cartridge was laid horizontally on what remained, being then in the very centre of the whole mass of powder; the remainder of the powder was now replaced in the cask, pouring it over the priming cartridge, the two wires being held up vertically; the head of the cask was now replaced, coopered up and hooped, the wires projecting through the holes in the head; two pine-wood conical plugs were now driven hard one into each hole in the head, beside the copper wire, so as to confine each in its own hole and keep all strain off the priming cartridge. The wires outside the cask were now insulated with calico and lac varnish as before and coiled up, and the casks were ready for firing, save that before each was buried, the hoops on the *lower* end only were nicked nearly through with a saw, and all removed but two, so that when the cask was buried standing on end with the firing wires uppermost

Section of cask and priming.

Diag. 7.



description. Some heard a noise, others felt a shock, while still others both heard and felt the effects of the explosion."—*Times.*

Very much of the effect in transferring the shock of the explosion of powder to a distance depends upon the sort of fulcrum upon which the explosion immediately acts. Thus I found, by a rough experiment made in Kingstown Harbour, that a single pound of powder, in a flat tin canister lying on the sand bottom, within about 60 feet of one of the granite piers and under about 35 feet in depth of sea-water, when exploded, actually shook the whole mass of the pier, or at least of the inner breast wall, on the coping of which we stood, so as to convey the idea at the moment that the whole was founded on a quagmire or peat bog. This remarkable effect I consider was due to the complete resistance afforded by the solid mass of water above the focus, so that the whole force of the explosion was expended in shaking the less homogeneous mass of the bottom on which the pier is built.

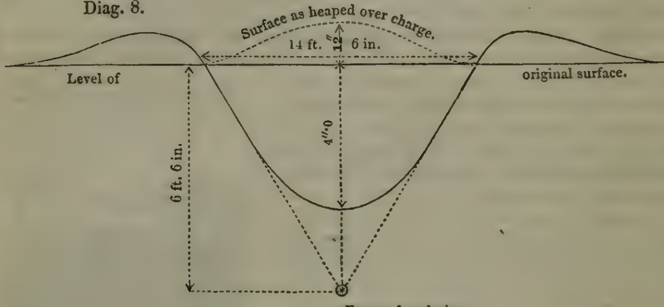
As to the distance to which the sound of explosion has been heard through the air, or through it and the earth in combination, the greatest on record is that of the tremendous eruption of Sumbava in April 1815, when the subterraneous noises were heard at Sumatra, 970 geographical miles away, and at Ternate, 720 geographical miles off, in the opposite direction nearly (Raffles's 'Java'); next to which is that of the reverberations of the volcano at St. Vincent's, which are said to have been heard at Demerara, a distance of 345 miles.

The noise of the cannonade at the battle of Jena, in 1806, was heard as a low murmur in the fields about Dresden, 92 miles away. It is almost certain that in this case the sound was transmitted through the earth, for it was heard with perfect distinctness in the casemates of the fortifications, where the vaults acted as acoustic instruments to collect the sound from the earth and convey it to the ear. It was stated at the time, but on what authority I cannot now say, that the cannonade at the siege of the Citadel of Antwerp, in 1832,

it should blow outwards the staves at the bottom, and thus most effectually act upon the superincumbent sand.

The following section shows the dimensions and form (which was a beautifully perfect paraboloid) of the holes blown out by each explosion in the sand, after being again partially filled up by the subsequent falling shower of sand.

Diag. 8.



Each cask was sunk as nearly as possible 6 feet 6 inches below the original surface, and about 1 foot deep of sand was heaped and rammed over the surface, making a total depth over centre of explosion of 7 feet 6 inches.

The next point of arrangement was to devise instrumental means for determining with perfect precision, the minute intervals of time that would elapse,—1, between the moment of ignition of the gunpowder and its complete explosion, or the time of "hang fire;" 2, the interval of time between the moment of ignition and the arrival at the seismoscope of the wave of impulse produced by the explosion, the difference in time between these two being the gross time of transit of the impulse through the given distance.

The beautiful instrument devised by Professor Wheatstone, and called by him the Chronograph, with some suitable additions and modifications, supplied all we required in this respect.

I had the advantage of Professor Wheatstone's own suggestions and advice, and a loan of one of his own instruments; a second I had constructed, by one whose subsequent loss science still deplores, the late Mr. Richard Sharp, chronometer-maker in Dublin.

As the construction of the chronograph has been fully described by its inventor in the Transactions of the Royal Society, it is needless here to repeat the details. It consists in fact of a small and finely-made clock deprived of its pendulum, but provided with a suitable catch by which the action of the weight upon it can be instantly arrested, or as immediately permitted to again act in giving it motion. The running down of the weight causes the anchor and pallets of the escapement rapidly to pass the teeth of the escapement-wheel, so that the clock "runs down" by a succession of minute descents,

was heard in the Saxon mines, which are 370 miles away; here the sound must also have travelled through the earth.

It would be desirable that those who have opportunity would extend our observations of this sort as to the relations between known percussive or explosive efforts, and the transfer of their efforts to ascertained distances through solid or fluid media, or through air. See also some observations on this subject in former Report on Earthquakes, and compare with the few records we as yet possess of the actual extent of movement of the earth's crust in earthquake shocks, &c.

each an accelerated one, and each equal to the preceding, and hence the run down is practically an uniform motion of the clock. It follows, that in proportion as the weight is added to, the velocity with which the clock runs down is increased, and hence by such additions the instrument may be made a measurer of more and more minute fractions of time.

Two dials and two hands register the revolutions, and parts of revolutions, made by the instrument. One hand is fixed upon the axis of the escapement-wheel (*a*, figs. 4, 5, 6, Pl. XIII.), and its dial is divided into 30 smaller and 6 larger divisions. The pinion on this axis has one-twelfth the number of teeth in the wheel (*b*) upon the weight barrel shaft, which carries the other hand, and hence one division of its dial (which has twelve divisions) corre-ponds to a whole revolution of the former dial.

I devoted Prof. Wheatstone's instrument to determining the time of "hang fire," and distinguished it as the Firing Chronograph; Sharp's chronograph was used for determining the time of wave transit, and became known as the Observer's Chronograph.

I now proceed to describe the peculiar additions made to these instruments for the purpose of starting and stopping their motions at the required instants; and first as to the Firing Chronograph. In Pl. XIII. fig. 2. is shown a front elevation of the whole instrument. *a*. The front of the clock and dials. *b*. The weight composed of shot poured into a small brass bucket attached by a silk string to the barrel and descending in the inside of the small clock case, the front door of which is removed in the figure. *c c*. The base of mahogany upon which the whole is secured. At the back of the instrument is a small lever, *d*, shown at full size in fig. 6, which is fixed on the arbor *e*, which carries also the lever *e f*.

The large brass lever *g* (figs. 2 and 6) is maintained always, except while under pressure from the hand, by means of a stout spring *h*, in close contact at the end next the clock with the lever *e d*, and while so in contact, the lever *e f* is held down upon the anchor *k* of the escapement, so as to prevent any motion in the clock although wound up; but as soon as the lever *g* is pressed down by the application of the hand on the end *m*, the small spring *n* pushes back the lever *e f* from the anchor *k*, and the clock begins to run down. The moment again that the hand is removed from *m*, the lever *m g* flies up, pushes back *e d*, and with it restores *e f* to its former position on the anchor *k*, and so instantly stops the clock.

But besides this, it was necessary that the same motion of the hand that started the clock into motion, should "make contact" with two separate galvanic batteries, one of which should act upon the other chronograph, and the second fire the mine.

The lever *m g* is of brass; it carries an adjustable copper wire *o*, dipping at its lower extremity into a cup of mercury *p*, into which is also inserted the long wire p^2, which leads to one pole of the "firing battery"; r^2 is the wire from the other pole dipping into the mercury cup *r*, which is connected by a fixed wire with another flat and shallow mercury cup *s* placed on the top of the wood pillar *r s*, and at such a level, that the hooked or turned down extremity *t* of the lever *g m*, hangs just clear by a quarter of an inch above the surface of the mercury when the chronograph is at rest.

The extremity of the lever at *t* is amalgamated, as are also all other connexions. It is now obvious that the instant the lever *g m* is depressed a quarter of an inch, by placing the hand upon it at *m*, contact is completed through r^2, *r*, *s*, *t*, *m*, *o*, *p* and p^2, and the mine or other charge fired.

But for reasons hereafter to be described, contact required to be made at precisely the same instant with a second galvanic battery also; for this

purpose a second brass lever *v w*, moving on the centre *w*, is provided, placed parallel to the other lever *m g*, and as close behind it as possible without touching, and on the same level, both on top. A mercury cup *x*, behind the lever *m g*, is provided, to receive the hooked or hanging down outer end of the lever *w v*, and the lever is kept up, except at the moment of and after depression, by the spring *z*. When therefore the lever *w v* is pressed down, contact is made between the poles of a second battery through y^2 conducting wire, the mercury cup *y*, the fixed wire *y x*, the lever itself dipping its amalgamated extremity *v* into the cup *x*, while its other end is connected by the mercury cup of brass and binding screw *w*, with the conducting wire w^2.

As it was necessary that this contact, when made, should be for some time maintained, the latch z^2 catches the top edge of the lever *w v* as soon as it is depressed, and holds it down into the mercury until relieved, when the spring *z* throws and holds it up again.

The backs or top edges of both levers, *m g* and *w v*, are covered with grooved slips of baked mahogany, to prevent electric contact with the hand.

Both are pressed down with perfect ease, and in the most absolutely simultaneous manner, by a sharp stroke or pressure from the flat palm of the hand pronated over them, and the instant the hand is removed, the clock already set in motion is again stopped.

I now proceed to describe the construction of the Observer's Chronograph, shown in Plate XIII. fig. 1. This chronograph required to be released or set in motion by the depression of the lever *w v* just described, and to be stopped by the hand of the observer at the seismoscope on the instant that the passage of the wave or impulse was seen in that instrument.

a is the clock and dial as before, *b* the weight in its case. At the back of the clock is a little iron flat lever (fig. 5, *c d*), on the same arbor with *c e*, which, as in the other case, presses on the anchor *f* of the escapement, and being constantly held upon it by the spring *g*, prevents any motion until it is withdrawn.

h (fig. 5 and fig. 1) is a round bar of iron $\frac{5}{8}$ths of an inch in diameter and 8 inches long, placed horizontally and secured by an iron arm to the clock case, so that one of its ends shall be within about $\frac{1}{10}$th of an inch of the surface of the little lever *c d*.

Round this bar is coiled about 500 feet of insulated copper wire placed between terminal discs of wood; when a galvanic current is passed through this coil, the bar *h* becomes a temporary magnet of considerable power, and acting on the lever *c d* as its armature, forcibly pulls its moveable extremity *d* towards the pole of the magnet, by which the lever *c e* is withdrawn from the anchor *f*, and the chronograph is set in motion.

The wires w^2 and y^2 in fig. 2 are supposed in continuation with those similarly lettered in fig. 1; and thus when the contact before described is made by pressing down the lever *w v*, electric communication takes place (through a mile or more of wire) through w^2, *l*, one end of the copper coil; *k*, the other extremity of it; and y^2, the battery, being supposed somewhere between.

This completes the arrangement for releasing or starting the Observer's Chronograph. For stopping it, a spring *l* is placed just above the anchor, in a convenient position to be kept under the point of the index finger of the observer while engaged in looking into the seismoscope; the instant he sees the disappearance of the cross wires therein, a slight pressure on the spring brings it into contact with the anchor and stops the chronograph; a binding screw *m* was provided above this, for the purpose of fixing the instrument from all chance of motion until the dials were read off and noted: this was

found however scarcely needful. Both the chronographs were screened from wind by being used within the fir-wood cases in which they were transported, the front sides of the cases being alone removed, or occasionally by a canvas screen; the weights of course descended in the closed mahogany clock cases of the instruments.

From what has been stated as to the effect of changing the moving weights of these instruments, it will be obvious that with any given weight it becomes necessary to rate the instrument, or to ascertain to what interval of actual time each revolution of the dials corresponds. This was done by winding up each instrument a given number of revolutions of the weight barrel, and having placed the instrument firmly before a good seconds' clock, noting repeatedly in how many seconds and parts of seconds it ran down the same number of revolutions; the clock used had a loud beat and a graduated arc to the pendulum, so as to enable a second to be divided by the eye into four parts at least.

Experimental rating of Wheatstone's (the Firing) Chronograph, 19th of October 1849.

Chronograph wound up in every case 8 revolutions.

Exp. 1.	8	revolutions	made in	$40''\cdot00$
2.	8	„	„	40·05
3.	8	„	„	39·75
4.	8	„	„	40·05
5.	8	„	„	40·00
6.	8	„	„	40·02
7.	8	„	„	39·95
8.	8	„	„	40·00
	No. of experiments		=8)	319·82
				39·98 average

for time of eight revolutions of large hand; ∴ value of one revolution of large hand is $=\frac{39\cdot98}{8}=4''\cdot9975$, hence value of one division of large dial $=\frac{4''\cdot9975}{12}=0''\cdot41646=1$ revolution of small dial, and 1 division of small dial $=\frac{0''\cdot41646}{30}=0''\cdot01388$.

To check this rating more completely, a method different from Wheatstone's, and I believe new, was adopted. A given number of seconds or beats of the clock was arbitrarily taken, the chronograph released at the first beat, and stopped dead at the last beat; 20 beats were taken, and in 20 seconds the same chronograph ran down by its own registry.

Exp. 1.	in $20''$	4	revolutions	-7°	small dial.
2.	„	4	„	-5	„
3.	„	4	„	$+7$	„
4.	„	4	„	-2	„

Nos. 1 and 3 rejected as bad experiments, then the average is $=4$ rev. $-3^\circ\cdot5$ small dial.

Taking then the value of one division of small dial from the first or preceding set of experiments $=0''\cdot01388$, then 4 rev. $-3^\circ\cdot5\times\cdot01388''=4$ rev. $-0''\cdot0486$; therefore $20''-0''\cdot0486=19''\cdot9514=$ the true time of 4 revolutions of large dial, or $\frac{19''\cdot9514}{4}=4''\cdot988$ time of one revolution of large dial

and $\frac{4''\cdot988}{12}=0''\cdot4157$=time of one division of large dial or of one revolution of small, and $\frac{0''\cdot4157}{30}=0''\cdot01386$; which differs from the preceding rating by first experiment only by 2 in the fifth decimal place.

The same mode of rating was applied to Sharp's (the Observer's) chronograph, on the 21st of October 1849, thus:—

Wound up 5 revolutions in every case.

Exp. 1.	5	revolutions	made in	$25''\cdot00$
2.	5	"	"	25·00
3.	5	"	"	25·00
4.	5	"	"	24·96
5.	5	"	"	24·85
6.	5	"	"	25·00
7.	5	"	"	25·00
8.	5	"	"	25·00

Rejecting experiments 4 and 5 therefore as probably inaccurate from the precise accordance of the others, we may take the time as 5 rev.$=25''\cdot00$, and $\frac{25''}{5}=5''\cdot00$ time of one revolution of large dial and $\frac{5''}{12}=0''\cdot4166$=value of one division of large dial=1 revolution of small, and therefore $\frac{0''\cdot4166}{30}$ $=0''\cdot013887$=value of one division of small dial.

These determinations were made for the experiments which were found abortive on the 25th of October 1849, and as it then became necessary to bring both chronographs into town and alter their attachments, it was requisite again to rate them before proceeding with the next trials; this was done as follows:—

Wheatstone's Chronograph, 29th of October 1849.

Seven revolutions ran down in all cases.

Exp. 1.	7	revolutions	made in	$35''\cdot50$
2.	7	"	"	35·75
3.	7	"	"	36·00
4.	7	"	"	36·00
5.	7	"	"	36·00
6.	7	"	"	36·00
7.	7	"	"	36·00
8.	7	"	"	36·00
9.	7	"	"	36·00

Rejecting experiments 1 and 2 as probably incorrect observations, we have the time of 7 revolutions$=36''$ or $\frac{36''}{7}=5''\cdot14286$=time of one revolution of large dial, and therefore $\frac{5''\cdot14286}{12}=0''\cdot42857$=time of one division of large dial=one revolution of small hand, therefore $\frac{0''\cdot42857}{30}=0''\cdot014206$ =the time of one division of small dial.

The rating of Sharp's chronograph was now performed by both the old and new methods, as it was to be used at the observing end of the line, and the utmost accuracy was there desirable.

Sharp's (the Observer's) Chronograph.

Five revolutions made in all cases.

Exp. 1.	5 revolutions made in		$24''{\cdot}50$
2.	5	„ „	24·70
3.	5	„ „	24·75
4.	5	„ „	24·80
5.	5	„ „	25·00
6.	5	„ „	25·00
7.	5	„ „	24·95
8.	5	„ „	25·00
9.	5	„ „	25·00

This gives an average of 5 revolutions made in $25''{\cdot}025=1$ revolution in $\frac{25''{\cdot}025}{5}=5''{\cdot}005$; 1 division of large dial therefore is $=\frac{5''{\cdot}005}{12}=0''{\cdot}4171$ $=1$ revolution of small hand, and $\frac{0''{\cdot}4171}{30}=0''{\cdot}013910=1$ division of small dial.

By the new mode of rating, taking an interval $=60''$ or beats of the clock, the revolutions made were as follow:—

Exp. 1 in $60''$ made	11 revolutions	+0·917	of one revolution	of large hand.
2 „ „	11 „	+0·972	„	„
3 „ „	11 „	+0·980	„	„
4 „ „	12 „	+0·042	„	„

The mean of which is $=11$ revolutions$+0{\cdot}978$ as that made in $60''$, which would be 12 revolutions in $60''{\cdot}1102$, or one revolution in $\frac{60''{\cdot}1102}{12}=5''{\cdot}0092$.

Taking now the mean of the first and second (or new) determinations, we have

$$\begin{array}{r} 5''{\cdot}0050 \\ 5{\cdot}0092 \\ \hline 2)10{\cdot}0142 \\ \hline 5{\cdot}0071 \end{array}$$

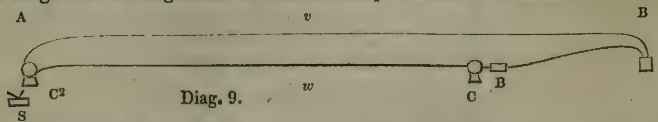
$5{\cdot}0071=$ the time of one revolution of the large dial, and $\frac{5''{\cdot}0071}{12}=0''{\cdot}41743=$ time of 1 division of the large dial $=1$ revolution of the small, and therefore $\frac{0''{\cdot}41743}{30}=0''{\cdot}013914=$ time of 1 division of the small dial.

To recapitulate, therefore: the following are the ratings of the two chronographs as used in the subsequent experiment of the 30th and 31st of October and 2nd of November 1849.

	One revolution of large hand or dial.	One division of large dial = one revolution of the small hand.	One division of small hand.
Wheatstone's....	$5''{\cdot}14286$	$0''{\cdot}42857$	$0''{\cdot}014206$
Sharp's	5·0071	0·41743	0·013914

Half a division of the small dial can be distinctly read; hence we could observe an interval as small as $\frac{0''\cdot013914}{2}=0''\cdot006956$, or less than, $\frac{7}{1000}$dths of one second.

The general arrangement at first contemplated was as follows:—



Diag. 9.

The range of half a mile extending from A to B, the powder was buried at P, one extreme; at the other was placed the seismoscope S and a chronograph C², so arranged, (see detail plate of apparatus) that on my releasing it, contact was made right through the whole line of both wires v^c and w through the firing batteries at B, and through a magnetic coil attached to the second chronograph at C (Sharp's), and so arranged that it released this chronograph at the moment contact was made by me: the wires, each of 3 twisted galvanized iron wires severally of No. 13 wire-gauge, were soldered together, and at first lying upon the sand, but afterwards insulated on wood-stakes. According to this arrangement, when contact was made at C², both chronographs were released at once. The moment the explosion took place, an assistant (William Mallet) stopped the chronograph C, placed within 150 yards or so of the charge; and as soon as the wave reached me and was seen in the seismoscope S, I stopped the second chronograph C²; the first chronograph C² showed the time of hang-fire, and the difference of these chronographs the gross time of wave transit.

On the 25th of October 1849 this scheme was tried, the battery power being 12 cells of Bergin's battery, the surface in action of each plate being already given. The cast iron in NO_5+SO_3+HO, opposed to two zincs in SO_3+HO; but it was found quite impossible either to release the chronograph C, or to fire the powder at this range. It could not be done even when both wires were completely insulated on wood stakes 4 or 5 feet high, driven into the sand; the battery wanted intensity.

On consideration, it was determined wholly to alter this arrangement and to fire from within a very short distance of the charge, and having two batteries at this point, one (Bergin's) to fire the powder, and another (one of Smee's with a large series of plates) to release by a magnetic coil the chronograph at the seismoscope end at the moment that contact was made simultaneously through both batteries and the whole range of insulated wire, the apparatus being such as to release the chronograph at the batteries to show the hang fire also.

Bergin's battery, as before, was used with 12 cells in action, the acids used being for the cast iron porous cells equal volumes of commercial nitrous acid and of commercial sulphuric acid and of water; and for the cells containing the zinc, one volume of sulphuric acid of commerce and eight volumes of water. Smee's battery consisted of 7 troughs in action, of silver and double zincs, 6 series in each, each plate having an acting surface (one side) of $2\frac{1}{2}$ inches wide $\times 3\frac{1}{4}$ inches deep, or in all a series of 42 pair of plates acting in SO_3+HO, diluted in the ratio of 1 volume of acid to 20 volumes of water.

On preliminary trials with priming cartridges only, this entire arrangement was found to act perfectly in all respects, firing the powder and releasing the chronographs with ease and certainty.

The following code of signals was fixed upon, as the length of the range

precluded communication by the voice. Three bannerols, blue, red and white, being provided for each end, a signal man (Sergeant Maberly, R.A. at the firing end, and a Gunner at the observing end), each with a look-out man provided with a telescope, was stationed at either extreme. All signals made were repeated in the same form to show that they had been observed and understood.

Signal Code.

White flag	Charge the mine.
White and red	Make connections.
Red	Prepare to fire.
Red dropped	Fire.
White and blue	Priming or charge has fired.
Blue and red	Stop.
Blue and red dropped	Proceed.
Blue	Send and receive message.

A man was stationed at half-distance to go to either end on being signalled. These signals were found sufficient, and after a little practice to work well; but on the latter days of experiment I found it convenient to have a led saddle-horse at hand to ride, if requisite, rapidly from end to end, to avoid the fatigue of walking through the deep loose sand. These preliminaries, including the operations of measuring the base line, were attended with so much labour and difficulty, everything having to be done on an exposed beach of deep sand peculiarly oppressive for walking on, and liable to frequent interruption from broken weather, that although commenced in July, the latter part of October had arrived before they were complete; fortunately, this month is ordinarily a peculiarly fine and steady one in Ireland, and that of 1849 was more than usually serene and calm; so that our experiments, when at length fairly commenced, promised well for success.

Everything being complete and the insulating stakes for the mile of conducting wires driven on the night of the 29th of October 1849, the following results were obtained on the 30th and 31st of October and on the 2nd of November 1849.

TABLE No. 1.

Date and number of experiment, and time of day when made.	Gross time shown by Chronograph at observing end = gross transit time. SHARP'S.	Time shown by the Chronograph at firing end = time of hang fire. WHEATSTONE'S.
No.		
1. 2 to 4 o'clock, Oct. 30, 1849.	$\overset{\circ}{8}$ large + $\overset{\circ}{26}$ small	$\overset{\circ}{0}$ large + $\overset{\circ}{22}$·0 small
2.	8 „ + 2 „	0 „ +22·5 „
3. 3 to 5 o'clock, Oct. 31, 1849.	9 „ + 0 „	0 „ +24·0 „
4.	8 „ +13·5 „	0 „ +21·5 „
5. 12 to 2 o'clock, Nov. 2, 1849.	9 „ + 9·5 „	0 „ +24·0 „
6.	9 „ +10·5 „	0 „ +22·5 „
7.	9 „ +15·5 „	0 „ +21·5 „
8.	8 „ +28·3 „	0 „ +22·0 „

On the 30th of October, the time of high water in Dublin Bay was 9^h 49^m A.M., hence the experiments Nos. 1 and 2 were made nearly at low

water, as was also the case with experiments Nos. 3 and 4, made on the 31st of October, when the hour of high water was $10^{h}\ 30^{m}$ A.M.

The sand in both these cases was thoroughly *wet* along the base line, but its interstices were not *filled* with sea-water higher than within perhaps 8 feet of the surface.

The experiments Nos. 5, 6, 7 and 8, the 2nd of November, when the time of flood tide was $11^{h}\ 57^{m}$ A.M., were, on the contrary, made nearly at high water, and in these cases the sand was saturated to within 2 or 3 feet of the surface.

Of the above eight experiments the only two upon which the least suspicion of inaccuracy can rest, are those of No. 3 and No. 5, in which I am rather doubtful of having stopped my chronograph with *absolutely* the same promptitude as in all the rest.

The error in excess of time, if any, however, could not amount to 3 divisions of the small dial $=3\times 0''\cdot013914$ in time, an amount so small and so much within the probable errors of observation, that I retain all the experiments as good results.

Deducting column the third in the above table from column the second, we get the following table No. 2, each column being previously brought separately into time, recollecting that the value of one division is different in each chronograph.

TABLE No. 2.

Showing the results of the experiments reduced to time, &c.

1. Date.	2. No.	3. Time noted at observing end by SHARP'S chronograph.	4. Time noted at firing end (hang fire) by WHEATSTONE'S chronograph.	5. Difference of columns 3 and 4, being the whole time of wave transit without corrections.
	1.	$''$ 3·701204	$''$ 0·312572	$''$ 3·388632
	2.	3·367268	0·319673	3·047595
	3.	3·756870	0·340984	3·415886
	4.	3·527289	0·305427	3·221862
	5.	3·889053	0·340984	3·548069
	6.	3·902967	0·319673	3·583324
	7.	3·972537	0·305427	3·667110
	8.	3·733206	0·312572	3·420634
Sums........		29·850424	2·557312	27·293112
And dividing each by 8, the number of the experiments, the averages will be thus:—				
Averages....		3·731303	0·319664	3·411639

And subtracting now the average of column 4 from that of column 3, we get for the whole time of wave transit—

$$\begin{array}{r} '' \\ 3\cdot731303 \\ 0\cdot819664 \\ \hline 2\cdot911639 \end{array}$$

$2''\cdot911639$ = whole time of wave transit for half a mile without correction.

The whole distance is half a mile=2640 feet; hence the gross ratio of transit per second is—

$$2''{\cdot}911639 : 2640 :: 1''{\cdot}000000 : x \; \frac{2640{\cdot}000000}{2{\cdot}911639} = 906{\cdot}705 \text{ feet per second.}$$

This has to be corrected for—

1st. Time of transit of the electric force along the wires of releasing and of firing.

2nd. Time of half-transit of the mercurial wave in the trough of the seismoscope, *i. e.* half the whole time of raising and transmitting this wave.

3rd. The personal equations of both observers.

And possibly a correction may arise from the time actually consumed in the *progress of the explosion* of each mine; for although an explosion conveys popularly the notion of *instantaneous* or *momentary* action only, yet, as we shall see, a very appreciable time is required to explode (*i. e.* consume) a large mass of powder.

The following experiments were undertaken to provide for this contingency; and having stated their results, I shall reserve the application of any corrections until after the description of our further experiments made in the granite.

TABLE No. 3.

Showing the whole time of "hang fire," from the moment of contact to that of explosions in primings and service charges.—*Note.* The results are all in the smallest divisions of the small dial, each $=0''{\cdot}014206$.

Date and No. of Experiment.		Whole time of hang fire service charges. WHEATSTONE'S chronograph.	Whole time of hang fire primings only. WHEATSTONE'S chronograph.	Difference = time of burning 25 lbs. of powder as exploded.
1849. Oct. 30.	1.	0· 22·0	0· 18·5	0· 3·5
	2.	0· 22·5	0· 20·0	0· 2·5
31.	3.	0· 24·0	0· 18·5	0· 5·5
	4.	0· 21·5	0· 21·0	0· 0·5
Nov. 2.	5.	0· 24·0	0· 17·5	0· 6·5
	6.	0· 22·5	0· 19·0	0· 3·5
	7.	0· 21·5	0· 18·0	0· 3·5
	8.	0· 22·0	0· none.	,, ,,
And reducing these into time as before, we have—				
Experiment	1.	0''·312572	0''·262811	0''·049721
	2.	0·319673	0·284120	0·035515
	3.	0·340984	0·262811	0·078133
	4.	0·305427	0·298326	0·007103
	5.	0·340984	0·248605	0·092339
	6.	0·319673	0·269914	0·049721
	7.	0·305427	0·255708	0·049721
	8.	0·312572	none fired.	none.
Sums..........		2·555412	1·882395	0·362253

I now proceed to record the results of the experiments made as to this *time of hang fire*, viz. the whole time from the moment of making contact with the firing battery to that of the explosion, as seen by the person firing; experiments being made both by firing primings only, as figured and described at page 277, and by primings and service charges of 25 lbs. of powder together.

The preceding table gives the results obtained by firing on each occasion of experiment a certain number of priming cartridges only, just after the service charges or mines, and hence with the batteries in as nearly as possible the same condition, and noting the time of burning of these by means of the chronograph.

Dividing each sum by the number of experiments, we get the following averages:—

A. $\frac{2''\cdot555412}{8}=0''\cdot319427=$average time of hang fire service charges.

B. $\frac{1''\cdot882395}{7}=0''\cdot268914=$average time of hang fire primings only.

C. $\frac{0''\cdot362253}{7}=0''\cdot051751=$average differences.

And deducting B from A, we find the average time for the explosion of 25 lbs. of powder, as fired under our conditions, was—

$$\begin{array}{l} 0''\cdot319427 \\ 0''\cdot268914 \\ \hline 0''\cdot050513=\text{time of explosion,} \end{array}$$

which is a little more than $\frac{5}{100}$dths, or about $\frac{1}{20}$th of a second.

I shall reserve such considerations as these experiments suggest until a subsequent period, when about to apply the several corrections to both classes of our experiments, and now proceed to describe the operations of the second series of

Experiments made in the Granite.

The experiments in the sand at Killiney being completed, a position was looked for to conduct those proposed to be made in the granite rock. After examining various possible ranges about Killiney Hills, &c., the Island of Dalkey was chosen as upon the whole the best locality presented.

This island is altogether of massive granite, very uniform in texture. The granite of which Killiney Hills and a large tract to the north-west, together with Dalkey Island, and seaward to the Mugglins Rocks, consist, is in mass of various tints of yellowish-white passing into grey. It is not quite so hard as Peterhead granite, sometimes found porphyritic, with large crystals of felspar, but more usually in a pretty equally diffused mass of rather fine grain, consisting of crystals of quartz, felspar and mica, often to a considerable extent replaced by schorl; solid masses present in working little "grain" or tendency to split more easily in one direction than another. It parts from the quarry usually in masses of an irregular trapezoidal form, averaging from 4 to 7 feet across; but solid blocks are easily got of eight times this mass. It is much intersected with quartz veins of various successive epochs, usually thin and perfectly adherent to their walls. The commoner imbedded minerals are—black schorl, garnet, killinite, spodumene, and more rarely apatite, beryl and fluorspar; some few others are much rarer. Three spe-

cimens of this granite of different size of grain had the following specific gravities:—

	sp. gr.
No. 1. Coarse grain	2·592
No. 2. Medium grain	2·655
No. 3. Fine grained	2·676

Mean specific gravity=2·641.

In its greatest length from north to south, the island admits of a tolerably level range of above 1600 feet. The general run of the beds, or rather fissures of the granite (or master joints), is about N.W. and S.E., while the best position presented for the experimental range is about N.N.W. and S.S.E.; thus giving as much solidity and freedom from the effects of discontinuity as the case admitted of (see map, Pl. XIV., and section, Plate XV.).

The island is owned by Government, and under the control of the Board of Ordnance, the grazing of the surface being rented from that Board.

By application through the favour of General Sir John F. Burgoyne, K.C.B., I obtained permission to make my experiments, subject to the approval of the local engineer officers at Dublin. The rentor of the grazing, a farmer, was next to be dealt with, and his permission was only had by paying him a sum of money and undertaking to make good all surface damage.

I then applied to the Board of Ordnance to permit me to purchase a sufficient quantity of the best government cannon gunpowder, finding it stated by Sir John Burgoyne, in his 'Treatise on Blasting,' that government powder is stronger and better than the best merchant powder, in the ratio of about 13 : 9.

Through the kind assistance of Sir John Burgoyne this permission was given, and the powder obtained from the Ordnance magazine, Phœnix Park.

I then roughly measured by the chain the best range I could lay out upon the island. I found I could get one excellent range of 1166 feet, or the choice of another and shorter one of 900 feet. In the former one, the end was not visible from the other extreme; but a ruined old church on the island, within about 400 feet of the firing end and visible from both extremities, gave the means of elevating the batteries for firing, &c., and the signal man, so as to answer as well as if the whole range were in view together.

Arrangements were now made for getting the holes jumped in the granite rock wherein to place the charges; and in order to form some notion of the quantity of powder that would be necessary to fire in each, a few preliminary experiments were made with blasts fired in the ordinary way in the granite of Glasthule Quarry, at Sandycove, near Kingstown Harbour, wrought by the Commissioners of Public Works, with a view to determine the effects upon the Seismoscope of various moderate charges. Three blasts were fired of the following depths of hole and charges. The two smaller holes were 2 inches diameter, the largest $2\frac{1}{2}$ inches diameter:—

6 feet depth of hole	6 lbs. powder,
8 feet depth of hole	7 lbs. powder,
10 feet depth of hole	8 lbs. powder,

tamped with clay in the ordinary way and fired with Bickford's patent fuse.

The Seismoscope was placed upon the solid granite rock, about 15 feet above the level of the holes, and at an average distance from them of 150 measured yards. On the 3rd of August, 1850, they were fired.

The wave of impulse through the granite produced in each of the explosions was distinctly visible in the seismoscope, but those of the two latter

charges more so than the first. The interval in time between the explosion and the disappearance of the cross wires of the Seismoscope was quite perceptible, notwithstanding the very short range, and gave the first indication of what experiment afterwards revealed as to the comparatively slow rate in which the pulse-wave moves even in granite rock.

These experiments led me to conclude that a single pound of powder would have given more than sufficient shock to have been perceptible in the Seismoscope at 300 feet range; and as the charge for equal pulses may be assumed (as before at Killiney) to vary as the square of the distance, then—

$$1\text{lb.} : 300\text{ft.} :: x : 1500\text{ft.},$$

or the charges should be as $5^2 : 1^2 = 25 : 1$, or for 1500 feet range, 25 lbs. of same sort of powder, as used at Glasthule, viz. from Ballincollig Mills. This however might be reduced at Dalkey for the government powder, in the ratio of 9 : 13, *i. e.* in the inverse ratio of their explosive powers, or the sufficient charge would be 17·3 lbs.

It was therefore determined to form the jumper-holes of a depth and size suitable to receive a charge of 20 lbs. of powder, and 12 feet in depth was fixed upon for each, with a diameter of cylinder of $3\frac{1}{2}$ inches nearly, being that made by a jumper of 3-inch gauge or width of edge.

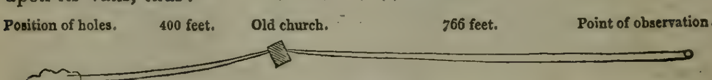
The next operation was to mark out the positions most suitable for the several holes to be jumped. This was done, and contracts made through Mr. Foot, foreman of works at Kingstown Harbour; boring tools being lent by the contractor for the harbour, Mr. M. B. Mullins, C.E., to whom I am indebted for this assistance.

On the 30th of September, 1850, the jumper-holes were finished; they were all nearly vertical, not many feet different in level from each other, and situated as in the map of the northern end of the island (Plate XIV.) and in section of range (Plate XV.).

The datum stone A remained a fixed point of solid rock to measure from, and an ordinate, A *b*, having been stretched out by a cord in the line of range, the position of each hole was found and referred to it by measured abscissæ; so that when, after the explosions, the whole surface of the rock constituting that part of the island should have been shattered and destroyed, the distances and positions at which the holes had been, should still be known.

From the 1st to the 25th of September was occupied in landing instruments and stores of various sorts upon the island, in which some difficulty was found, owing to the period of the year, the stormy state of the weather, and the powerful run of tide and heavy sea that sets through Dalkey Sound.

The arrangements for firing and for noting the times were precisely similar to those used at Killiney Strand. Two distinct batteries, one of Bergin's of 12 pair of plates, being used for firing, and 5 troughs, or 30 pair of plates of Smee's battery, for releasing the chronograph at the observer's end. The batteries were placed at the ruined church (see Map) upon a scaffold covered by a temporary splinter proof, and placed nearly at the top of the old church upon its walls, thus:—



Diag. 10.

The distance from the congeries of jumper-holes to the church was about 400 feet. On the 2nd of October, 1850, a preliminary experiment was made as to the firing power upon priming cartridges, when it was found that the intensity of 12 pairs of Bergin's battery (reduced by the low temperature of

this advanced season) was too feeble to fire at this distance, and accordingly 12 more pairs of plates were added, and the whole of the apparatus removed from the church to a point a little to the westward and within about 250 feet of the most remote hole (A in map, Plate XIV.), where it was found that signals could be seen and repeated from the remoter end of the range by taking advantage of some elevated points of rock. The whole of the scaffolding, which had cost so much labour and trouble, thus became useless, and a new splinter proof had to be constructed from its materials.

On the 3rd of October, these new arrangements having been completed, a second preliminary experiment was made, when it was found that the priming cartridges could be instantly and certainly fired with the increased power of Bergin's battery, and that the Smee's battery also released the chronograph at the remote end wall; in a word, that all was perfect.

The positions of the instruments were now precisely as already described at Killiney Bay, except that all the firing batteries and apparatus were placed upon a convenient table or platform about $2\frac{1}{2}$ feet from the ground, formed out of the abandoned scaffolding of the church.

Both the conducting wires were supported on dry wood stakes, from which they hung by loops of gutta percha through the entire distance. The position for the chronograph at the observer's or seismoscope end having been fixed upon, a flat table was cut down upon the face of the solid rock at nearly the most elevated spot upon the island to form an efficient bed for the Seismoscope, the bottom plate of which was so let into the rock as to be firmly grasped by it, as seen in Pl. XV., lower figure.

Four holes, $1\frac{1}{2}$ in. diam. and 6 in. deep, were jumped in the rock round the Seismoscope, and a canvas screen, stretched on upright inch-round iron rods socketed into the holes, was erected to keep off all wind from the Seismoscope; which was found of great service.

The priming cartridges for firing the blasts had been prepared in a peculiar manner, inserted in sticks of dry pine of 8 feet in length, in a groove down one side of which the $e+$ wire passed, and up a similar groove at the other the $e-$ wire passed, both imbedded in a cement composed of pitch and wax. The priming powder was fine rifle-glazed gunpowder, the copper wires $\frac{1}{16}$th of an inch diameter (16 wire-gauge). The platina wire was such that 2 inches weighed 1·62 grain; it was wrapped round with gun-cotton, the powder poured round it; one side of the recess or mortice, which was cut quite through the wood, being closed by brown paper pasted on, and the whole then closed by brown paper pasted over, and also over the whole stick, which was then roughly varnished over with pitch and wax, laid on hot so as to exclude moisture (see Pl. XVI.). One side of each stick was rounded to fit the curved side of the cylindrical jumper-hole, so as to admit of the tamping being driven well home; and the enlarged lower extremity was cut wedge-shaped, so as to bind in the tamping when the blast should be fired.

The priming was so placed in each hole as to be a little below the centre of the depth of the powder, which occupied about 6 feet in depth of each hole, leaving about 6 feet for tamping. The tamping was dry yellow loamy clay, the same as used at the Killiney quarries in the operations for getting granite stone for Kingstown Harbour. The tamping was driven home after the first few inches of clay over the powder with a round iron bar of about $\frac{7}{8}$ths of an inch diameter, which was found to work most effectively, and the priming sticks were not found to offer any obstruction to the perfect tamping of each hole. The priming sticks themselves gave a most complete resistance to the explosions for their own section of each hole, as their subsequent condition proved, each stick, with but one exception, being pounded on end into chaff,

in which the priming-stick was launched to a surprising height in the air. The final junctions between the batteries and the priming cartridge wires were made by brass binding screws, leaving but one point of broken contact to be made good, namely that at the firing chronograph.

Previous to the two chronographs being brought out and landed on Dalkey Island, they were both timed by the seconds' clock in Dublin as before. The following is a record of these timings.

The chronograph was wound and let run down a known number of complete revolutions in each experiment, and the seconds and fractions in the time taken to do so noted by reckoning the beats of the seconds' clock and observing the place of the pendulum over the graduated arc at the moment of completing the revolutions.

Eight experiments were made in each case, in four of which the writer started and stopped the chronograph and William Mallet observed the clock, and in the other four he started and stopped and the writer observed the clock. Then, averaging the whole, the personal error was got rid of in each case.

The personal equations for both observers were also arrived at from these experiments, but require repetition before a result applicable to the main purpose of these experiments themselves can be had.

The following table gives the results of the experiments for timing of Wheatstone's chronograph, which was that used at the firing end of the range, and Sharp's chronograph at the transit or observing end.

Wheatstone's Chronograph. 20th Sept. 1850.

Eight revolutions made in all cases.

Exp. 1.	8 revolutions made in		38·0″	Clock observed by Wm. Mallet.
2.	8	,, ,,	37·5	
3.	8	,, ,,	38·0	
4.	8	,, ,,	38·25	
5.	8	,, ,,	38·75	Clock observed by Robert Mallet.
6.	8	,, ,,	39·0	
7.	8	,, ,,	39·0	
8.	8	,, ,,	39·0	
			8)307·05	
			38·38	average,

or eight revolutions made in $38''\cdot38 = \frac{38''\cdot38}{8} = 4''\cdot798$ time of one revolution of large dial. One division of the large dial is therefore $= \frac{4''\cdot798}{12}$ $= 0''\cdot3991$, also equal one revolution of the small dial, and $\frac{0''\cdot3991}{30} = 0''\cdot0133$ equal one division of the small dial.

The personal equation deducible from the above is as follows. All William Mallet's observations are of shorter times than mine, and assuming the chance of error equal in each case,

Wm. Mallet's four observations.

Exp. 1.	38·0″
2.	37·5
3.	38·0
4.	38·25
	4)151·75
Average	37·937

This divided by 8 revolutions = $4''\cdot742$ = time of one revolution of large dial.

R. Mallet's four observations.

Exp. 5.	38·75″
6.	39·0
7.	39·0
8.	39·0
	4)155·75
Average	38·937

This divided by 8 revolutions = $4''\cdot867$ = time of one revolution of large dial.

Then

$$\begin{array}{r} 4{\cdot}867 \\ 4{\cdot}742 \\ \hline 0{\cdot}125 \end{array} \text{ total difference,}$$

and $\frac{0''{\cdot}125}{2} = 0''{\cdot}0625 =$ the error in defect for one and in excess for the other observer, viz. in defect for W. Mallet and in excess for R. Mallet. Then, as $0''{\cdot}0625 =$ error for one revolution of large dial, $\frac{0''{\cdot}0625}{12} = 0''{\cdot}0052$ = error for one division of large dial, or = one revolution of small dial, and $\frac{0''{\cdot}0052}{30} = 0''{\cdot}000174 =$ one division of small dial.

If, instead of the operation adopted, we take the arithmetic mean,

$$\begin{array}{r} {}'' \\ 4{\cdot}867 \\ 4{\cdot}742 \\ \hline 2)9{\cdot}607 \\ \hline 4{\cdot}8045 \end{array}$$

and then take the difference between each extreme and this mean,

$$\begin{array}{r} {}'' \\ 4{\cdot}8670 \\ 4{\cdot}8045 \\ \hline 0{\cdot}0625 \end{array} \qquad \begin{array}{r} {}'' \\ 4{\cdot}8045 \\ 4{\cdot}7420 \\ \hline 0{\cdot}0625 \end{array}$$

the result will be the same.

The timing of Sharp's chronograph was now proceeded with, and as the whole period to be measured (in the granite) was expected to be much shorter than in the Killiney sand, and hence greater accuracy was needed, some weight was added to make this chronograph run faster than on occasion of the experiments there, on principles already explained.

Sharp's Chronograph (observer's end). 20th Sept. 1850.

Five complete revolutions made in each experiment.

Exp. 1.	5	revolutions	made in	″ 21·00		
2.	5	„	„	21·25		Wm. Mallet observed the clock.
3.	5	„	„	21·00		
4.	5	„	„	21·25		
5.	5	„	„	21·80		
6.	5	„	„	21·50		Robert Mallet observed the clock.
7.	5	„	„	21·45		
8.	5	„	„	21·75		
				8)171·00		
				21·375		

or five revolutions made in $21''{\cdot}375$, then $\frac{21''{\cdot}375}{5} = 4''{\cdot}275 =$ time of one revolution of large dial, and $\frac{4''{\cdot}275}{12} = 0''{\cdot}35625 =$ time of one division of large dial, or of one revolution of small dial, and $\frac{0''{\cdot}35625}{30} = 0''{\cdot}011875 =$ time of one division of small dial, the half or even quarter of which being capable of being read off the instrument is sensible to $\frac{0''{\cdot}011875}{4} = 0''{\cdot}002969$, or to about $\frac{3}{1000}$dth of one second.

The personal equation derivable from these experiments is as follows:—

W. Mallet's observations.

Exp. 1.	$21''\cdot00$	
2.	$21\cdot25$	
3.	$21\cdot00$	
4.	$21\cdot25$	
	$4)84\cdot50$	
Average	$21\cdot125$	

Divided by 5 revolutions $=4''\cdot225$ = time of one revolution of large dial.

R. Mallet's observations.

Exp. 5.	$21''\cdot80$	
6.	$21\cdot50$	
7.	$21\cdot45$	
8.	$21\cdot75$	
	$4)86\cdot50$	
Average	$21\cdot625$	

Divided by 5 revolutions $=4''\cdot325$ = time of one revolution of large dial.

Then

$$\begin{array}{r} 4''\cdot325 \\ 4\cdot225 \\ \hline 0\cdot100 \end{array} \text{ total difference,}$$

and $\frac{0''\cdot100}{2}=0''\cdot05=$ the error in defect in W. Mallet's observations and in excess in R. Mallet's. Then, as $0''\cdot05=$ the error for one revolution of large dial, $\frac{0''\cdot05}{12}=0''\cdot00417=$ error for one division of large dial, or for one revolution of small one, and $\frac{0''\cdot00417}{30}=0''\cdot00014$ error for one division of small dial.

Everything being now prepared, and a remarkably calm and fine day presenting on the 3rd of October, 1850, the several workmen and gunners were collected on the island, and the experiments actually commenced at about 10 o'clock A.M. were completed by 6 o'clock P.M., the accurate admeasurement of the base line or range from the datum stone A, near the blasts, to the observation station at seismoscope, being left for a future day.

Ten holes in all had been prepared for blasts, and five were charged and tamped at once to avoid damping the powder by its remaining too long in the holes. Each hole received from 18 to 20 lbs. of powder. They were fired (the first five first, and then the last five) in the order or number of the experiments in the following table. The letters attached in the second column refer to the Map, and show the position of the blasts in the order in which they were fired, it having been deemed expedient to fire in succession those least likely to run into each other, and so, by the fractures produced, spoil the effect of the subsequent ones.

There was one hole (G) a "wet one," *i. e.* a run of water into it; but it nevertheless fired well and gave a good result, having been stopped with clay before charging. Only two of the holes "threw" much rock to any distance, the whole force of the charge being expended in all the others only in rending and shaking the rock. Not one gave a loud report; nothing beyond a low, hollow groan. In one case (D), a solid mass of rock, weighing by measurement from 90 to 100 tons, was shifted horizontally from its bed, not less than 25 feet having been fractured from the parent rock on three sides.

TABLE No. 4.

Dalkey Granite Experiments, Wave-Transit, October 3, 1850.

No.	Place of blast on Map.	Total distance from the centre of effort of blast to seismoscope.	Gross time shown by the chronograph at observing or transit end. SHARP'S.	Gross time shown by chronograph at the firing end = time of hang fire. WHEATSTONE'S.
		feet.	° ″	° ″
1.	A	1155	3 7·5	0 17·0
2.	B	1121	2 10·0	0 19·0?
3.	C	1107	3 4·25	0 19·5
4.	D	1023	3 4·0	0 18·5
5.	E	1021	3 2·5	0 17·0
6.	F	1150	3 9·0	0 18·5
7.	G	1054	3 0·5	0 17·0
8.	H	1040	2 11·5	0 17·0
9.	I	1027	2 22·0	0 18·0
10.	K	1068	2 14·5	0 17·5

TABLE No. 5.

Being the preceding Table reduced into actual time, from the values of the Chronograph Dials as given in preceding pages.

No.	Place of blast on Map.	Gross time of transit or observing chronograph. SHARP'S.	Gross time of firing chronograph. WHEATSTONE'S.	Difference between the times of the two chronographs, being difference between the two preceding columns = whole time of wave-transit without correction.
1.	A	1″·15796	0″·2261	0″·93186
2.	B	0·83135	0·2527	0·57865?
3.	C	1·11937	0·2593	0·86007
4.	D	1·11640	0·2460	0·87040
5.	E	1·09859	0·2261	0·87249
6.	F	1·17577	0·2460	0·92977
7.	G	1·07484	0·2261	0·84874
8.	H	0·84916	0·2261	0·62306
9.	I	0·97385	0·2394	0·73445
10.	K	0·88489	0·2327	0·65219

Table No. 6.

Being the Results of all the preceding experiments reduced to one uniform range or distance of 5280 feet, or *one statute mile.*

No.	Map point of blast.	Actual range of experiment. $n.$	Actual time of wave-transit without correction. o	Transit time reduced to one uniform range of 5280 feet. $p.$
1.	A	1155	0″·93186	4″·2686
2.	B	1121	0·57865	2·7255*
3.	C	1107	0·86007	4·1022
4.	D	1023	0·87040	4·4924
5.	E	1021	0·87249	4·5120
6.	F	1150	0·92977	4·3558
7.	G	1054	0·84874	4·2518
8.	H	1040	0·62306	3·1632
9.	I	1027	0·73445	3·7758
10.	K	1068	0·65219	3·2243

In the preceding Table the value of each transit time is proportionate to the *actual range*; therefore in taking the mean each individual range is to be multiplied into its time per mile, and the sum divided by the sum of the ranges for the true mean.

Table No. 7.

$n \times p.$	Or,
A......4930.2330	1. { Sum of A, B, C, D, E, F, G=31219.1378.
B......3054.7250	Divided by 7631=4″·0911.
C......4541.1354	
D......4595.7252	
E......4606.7520	2. { Sum of A, C, D, E, F, G=28164.4128.
F......5009.1700	Divided by 6510=4″·3263.
G......4481.3972	
H......3289.7280	
I......3877.7466	3. { Sum of H, I, K=10611.0272.
K......3443.5524	Divided by 3135=3″·3847.

Means of Means.

Mean of 1 and 2............. = 4″·2087
Mean of 2 and 3............. = 3·8555
Mean of 1 and 3............. = 3·7379
Mean of 1, 2 and 3........... = 3·9340

Adopting the experiments A, C, D, E, F, G on the more shattered granite as a separate set, their gross mean is 4″·3263 of time of transit for one mile.

And also adopting the experiments H, I, K on the more solid mass of granite as a separate set, their gross transit time is 3″·3847 of time for one mile.

* This experiment is doubtful.

The first gives a transit rate uncorrected of 1220·44 feet per second.

The second gives a transit rate, uncorrected, of 1559·96 feet per second, to which is to be applied the seismoscope and other corrections, which will be reserved for future notice.

It will at once occur to the reader,—Why thus divide one series of experiments into two separate sets? This requires explanation. If the medium (granite) in which these or any similar experiments were made, were of perfect homogeneity, the results of every separate experiment should closely approximate within the limits of probable experimental error. The results given in the preceding tables however are divisible at a glance into two sets, each respectively very closely approximating; viz. the sets A, C, D, E, F, G on the one part, and those of H, I and K on the other; while these respectively differ, on the average, in the ratio of 4·3263 to 3·3847.

This result had been anticipated before the experiments were made.

The granite chosen for all the explosions was the most homogeneous that could be commanded, still none of it was absolutely so; nor probably does a mass of rock exist upon the earth's surface that is homogeneous, *i. e.* free from master joints, clefts and fissures, for a quarter of a mile in extent in any direction; and of the ten jumper-holes here employed, those from A to G inclusive were of necessity placed in granite of a more fissured or shattered character than the three others, viz. H, I and K. These three last ones, as may be seen by the Map, were driven into one vast boss (roche moutonée) of granite absolutely free, so far as it was exposed to view from immediate fractures, and from its appearance extending down to a great depth into the very foundations of the island before reaching any great fissures. Thus it follows that the transit rate ascertained (or the experiments A to H inclusive) belongs to an impulse wave transmitted through granite of the ordinary degree of fissuring found in the great mass of European granites, while that of H to K belongs to the same rock in a more solid condition, and approaching much more nearly to the transit rate that would be due to the same granite, if for the whole length of range it constituted one unbroken, perfect and homogeneous mass of rock. We will return to this when finally discussing the results of our experiments, and now proceed to describe some subsidiary experiments, the propriety of making which was suggested by the results obtained in those devised as principal.

The large difference in transit time between the wave in loose sand, as found at Killiney, and that in granite, as found at Dalkey, viz. between 906 feet per second in round numbers, and 1220 feet per second the average *minimum* in granite, might seem sufficient to establish at once that the pulses observed in each case in the Seismoscope must have been truly due to vibrations propagated through the earth, and could not be due to any commotions of the air above, produced by the report or concussion of the powder. But as both these transit times do not differ enormously from the admitted transit period of the ordinary sound-wave in air, it seemed desirable to put beyond doubt any question as to this source of fallacy in the experiments.

It is to be borne in mind that at Killiney Bay the noise or report of the explosions was in every case so deafened by the dead sand, as to be scarcely heard at the seismoscope; and that at Dalkey, although the reports were more distinct, there was no explosion heard at the seismoscope louder than that of two or three muskets at, say 100 yards off, and not nearly as sharp or ringing; nor this but from two of the blasts, the others producing as little report as any mine at Killiney Bay. Aërial commotion is therefore at the outset improbable.

To set the matter experimentally at rest, however, eight jumper-holes

were formed at Glasthule Quarry in granite, at the same place at which the first preliminary trial blasts were fired, and the same station as then was again chosen for the Seismoscope, being at a range or distance of 150 yards.

Upon the top edge or lip of the mercurial trough of the seismoscope a thick plate of glass was ground air-tight, and an exhausting syringe was so attached that a pretty good vacuum could be formed between the level plate of glass covering the mercurial trough and the mercury therein, and the whole so arranged that disturbance of the mercurial surface caused the cross wires to disappear as usual, when seen through the glass plate reflected from the mercury.

A wooden box of 3 feet square and 15 inches deep was also prepared, and filled evenly and carefully with well "teased out" curled hair, such as is used for stuffing cushions; upon the top of which was placed a square flat board of one inch thick, whose surface dimensions were an inch less each way than those of the box inside. The box, when resting level on the rock, was so adjusted that the seismoscope could be sustained in a level position (floating as it were on the curled hair-spring mattress) on the centre of this square board.

These preparations having been made (the latter end of October), a very calm day was chosen, and the jumper-holes having been charged with about 4 lbs. of powder each, the seismoscope was first placed upon the bare solid granite, the plate of glass and the telescopes adjusted, and the air exhausted from above the mercury. Then four of the blasts were fired in succession, and the amount of disturbance of the cross wires noticed. The range was too short to count the *time* of wave-transit by any method, and the shock was sufficient to cause the cross wires to disappear completely more than once, generally twice, at each explosion.

The double disappearance is a very interesting fact. It is most probably *the transit of the normal, and then of the transversal wave, rendered visible to the eye for the first time*, and seems to indicate that by a sufficiently delicate modification of the Seismoscope and chronographic apparatus the interval in time between their consecutive arrivals might be ascertained, and thus much insight gained to the so far obscure or unknown relations that subsist in a vibrating mass between the mutual displacements and the elastic compressions of its molecules, in virtue of which, even in homogeneous bodies, the wave becomes one of two sheets.

This being done, the box of curled hair was placed upon the solid granite, the Seismoscope upon it, the plate of glass removed, and the whole adjusted, the air having free access to the mercury. In this condition the other four jumper-holes were fired, and the amount of disturbance of the cross wires observed; an attempt also was made to note the brief interval of time elapsing between the flash or smoke (observed in the former and latter case by an assistant and chronograph) and the disappearance of the cross wires, when announced by the observer.

In the former condition of the instrument, the mercury cut off from any direct contact with the atmosphere and resting on the solid rock, was in the best possible position for being affected by the wave through the earth, and in the worst possible position for being moved by the wave through the air; while in the latter condition it was, as far as possible, cut off from any direct contact or hold on the solid ground by the supporting cushion of curled hair, and the mercury itself was freely exposed to the vibrations of the air, while the whole instrument, resting upon a large flat, dry, deal sounding board, was in the best position to be powerfully affected by pulses if communicated through the atmosphere.

The result of these experiments was, that—

1. No perceptible difference in time or transit period could be estimated between the flash or explosion and disappearance of the cross wires, in either condition of the instrument.
2. The actual amount of motion of the mercury was perceptibly greater in the case where the seismoscope stood on the solid rock, with the air exhausted above the mercury.
3. The cross wires were longer in coming again to rest in the second case, where the instrument stood on the curled hair-box and was freely exposed to air.

Hence I conclude that in each case the whole effect was due to the stroke conveyed through the earth, and none of it to that conveyed through the air, which seemed too feeble to affect the instrument, though greatly louder than at either Killiney or Dalkey.

Lastly, to put at rest the possibility of the mercury in the Seismoscope being disturbed by even a pretty loud and near atmospheric concussion, I adjusted it on a surface perfectly at rest in the open air, and fired a rifle gun (No. 14 bore of barrel) with about four drachms of powder for each charge of blank cartridge, repeatedly at various distances and in various directions with respect to the instrument, the report in each case being fully as loud and sharp as that of a common musket. The results were, that up to within 30 feet or thereabouts of the instrument no disturbance was produced in the image of the cross wires, when the rifle was held horizontally and loosely in the hands, and pointed away from the instrument. At or within this distance, if pointed towards the instrument and held to the shoulder, or still more if held to the shoulder firmly and pointed vertically upwards, a very slight disturbance could be noticed; but beyond 30 or 40 feet radius round the seismoscope the effects of the discharge were nil. As in each case these explosions were enormously louder and more ringing than any one of those heard either in the experiments at Killiney Bay or at Dalkey Island, I conclude it impossible that any movement or commotion of the air due to the experimental explosions can have in any way interfered with or perplexed our results.

From the construction of our instruments and nature of the experiments already recorded, it will have been remarked, that the degree of accuracy attainable, independently of mere instrumental error, *i. e.* the probable observational error, depends upon the degree of consent between signal by the eye and hand, as respects both observers, viz. the firing party and the observing party—the first of whom stopped his chronograph by hand on seeing the explosion, while the latter stopped that instrument at the further end of the range, by hand on seeing the disappearance of the cross wires of the Seismoscope. Some experiments therefore of a sufficiently like character, to determine the degree of accuracy to which this consenting action of eye and hand existed, in both observers, and in what relation to each other, seem necessary. These are as follow.

Experiments for the Determination of the Personal Equations of the Experimenters.

These were made with Wheatstone's chronograph and a seconds' beat clock, with graduated arc to the pendulum.

In the first case one observer counted 30″ by the clock, pronouncing the word *now* at the beginning of the first and end of the last second, while the other obserer started and stopped the chronograph, and then the two ob-

servers changed places and repeated the experiments. The following are the results of eight good experiments.

No.	A. William counts the clock, Robert starts and stops.	B. Robert counts the clock, William starts and stops.	C. Column A[1] reduced to time from the chronograph rates already given.	D. Column B[1] also reduced to time in same way.
	°	°	″	″
1.	6 0·9	6 0·7	28·9077	28·8811
2.	6 0·3	6 0·19	28·8279	29·0407
3.	6 0·12	5 11·22	28·9476	28·6727
4.	5 11·9	6 0·28	28·4998	29·1604
5.	6 0·5	5 11·14	28·8545	28·5663
6.	6 0·14	6 0·2	28·9742	28·8146
7.	6 0·9	5 11·25	28·9077	28·7126
8.	6 0·5	6 0·1	28·8545	28·8013
		Means	28·8467	28·8312

The figures of columns *A* and B mark revolutions of large dial divisions, *i. e.* $\frac{1}{12}$th of the large dial, and divisions, *i. e.* $\frac{1}{30}$th of small dial of Wheatstone's chronograph, its time being in value the same as when used at Dalkey experiments.

As there seemed to be two sources of error of observation in this mode of experiment, another set of eight good experiments was made, in which the same observer counted the clock, and himself started and stopped the chronograph; and the results below give the readings of the instrument as by each observer for the same epoch of 30 seconds.

No.	A². Robert counts clock, and starts and stops a chronograph.	B². William counts clock, and starts and stops a chronograph.	C². Column A² reduced to time from the chronograph rating as before given.	D². Column B² reduced to time in same way.
	°	°	″	″
1.	6 0·20	6 0·10	29·0540	28·9210
2.	6 0·6	6 0·7	28·8678	28·8811
3.	6 0·10	6 0·7	28·9210	28·8811
4.	6 0·11	6 0·17	28·9343	29·0141
5.	6 0·7	6 0·10	28·8811	28·9210
6.	6 0·18	6 0·20	29·0274	29·0540
7.	6 0·11	6 0·23	28·9343	29·0939
8.	6 0·15	6 0·25	28·9875	29·1205
		Means	28·9509	28·9858

The figures of columns A² and B² represent revolutions of large dial divisions of $\frac{1}{12}$th thereof, and divisions of small dial of $\frac{1}{30}$th thereof, as before.

	Means of C and D.	Means of C² and D².
Differences of the means....	$0''\cdot0155$	$0''\cdot0349$

These results seem to agree pretty well with the American ones as to the degree of consent between eye and ear, or eye and hand, in observational experiments, which gave a probable error for the same observer of about 0·01 of a second; the mean of the error for both the preceding experiments would be

$$\begin{array}{r} 0{\cdot}0155 \\ 0{\cdot}0349 \\ \hline 2)0{\cdot}0504 \\ \hline 0{\cdot}0252 \end{array}$$

or nearly double the American error. But the error for observation with the chronographs, where stopped by *hand* on *seeing* the seismoscope wave, would be less, probably not more than the American results on experiments to ascertain difference of longitude by the electric telegraph; and as two observers were engaged at the same experiments, viz. William and myself each at his own chronograph, the probable error of these experiments may be expressed by $\sqrt{2} \times 0{\cdot}01$ or $\sqrt{2} \times 0{\cdot}0252$, according to which mean time error be taken.

We are now in a position to apply the necessary corrections to the first results ascertained for the transit periods both in the sand and in the granite.

The first correction (see ante), viz. for the time lost by the transit of the galvanic current through the conducting wires used in our experiment, may be neglected; for assuming Wheatstone's coefficient of 288,000 miles in $1''$ as its velocity, the total time in the first series is only $\frac{1}{288000}$dth of a second, and in the second only about one-half of this, both being portions of time far within the limits of possible observation or of instrumental error.

The details which have preceded as to the experimental determinations of the probable observational errors, show that any corrections for personal equation are also here a needless refinement. The personal errors indeed were of such a character as to tend to their mutual extermination.

The only correction then to be made resolves itself into that for the time lost in the production and transmission (through half the length of the mercurial trough of the instrument) of the wave in the seismoscope.

Referring to page 281 we found that the time *lost* in forming and transmitting this wave of the seismoscope, amounted to $0''{\cdot}065$; this appears to *delay* the arrival of the earth-wave or elastic pulse through the medium under experiment in its arrival at the instrument. Hence the correction is to convert this time into distance, and *add* it to the first result given by experiment.

We found that the gross rate of wave-transit in the sand was

906·705 feet per second.

Converting $0''{\cdot}065$ in time into distance, at this rate we have

$$\frac{906{\cdot}705 \times 0''{\cdot}065}{1''{\cdot}0} = 58{\cdot}9358 \text{ feet};$$

and we thus get the final result,

$$906{\cdot}705 + 58{\cdot}936 = 965{\cdot}461 \text{ feet per second},$$

the transit rate in the sand at Killiney Bay.

So for the experiments in the granite we found—for the minimum result in jointed granite—the transit rate, uncorrected, of

1220·44 feet per second;

and the maximum result in the most solid granite tried was, uncorrected,

1559·96 feet per second.

x 2

For the seismoscope wave, the former correction is

$$\frac{1220{\cdot}44 \times 0''{\cdot}065}{1''} = 79{\cdot}30 \text{ feet},$$

and the latter

$$\frac{1559{\cdot}96 \times 0''{\cdot}065}{1''} = 101{\cdot}40 \text{ feet};$$

and adding these to the uncorrected rates, we obtain the true transit rates:—For jointed granite $1220{\cdot}44 + 79{\cdot}30 = 1299{\cdot}74$ feet per second, and for the more solid granite $1559{\cdot}96 + 101{\cdot}40 = 1661{\cdot}36$ feet per second.

We have now experimentally ascertained, with considerable accuracy, the rate at which an elastic wave of impulse is transmitted through two distinct media, sand and granite, which, as being perhaps the worst and the best for the rapid transmission of such movements to be met with in extensive masses on the surface of the earth, may be viewed as those in which *the limits* of wave motions, analogous to those of earthquake waves, are to be found.

The results are as unexpected as remarkable. In the original memoir upon this subject, published in the Transactions of the Royal Irish Academy, vol. xxi. part 1, on the hypothesis that earthquake waves were true waves of elastic compression, I ventured to conclude that their transit rates in various solid and homogeneous media would be found to be proportionate to the square roots of their moduli of elasticity. What the transit rate might be in discontinuous or interrupted media, I could not venture even to guess. It was not without surprise, however, that I found it in sand reduced so low as under 966 feet per second; and this was again increased, when it proved in granite not to exceed a maximum of 1662 feet per second; the former falling below the rate of ordinary sound in air about as much as the latter rises above it. Had I been asked beforehand what velocity I expected to find in solid granite, I should have replied, possibly 8000 feet per second, or more; but the extremely low velocity previously found in the sand had in some degree prepared me to expect one of lower value in the granite, and on careful review of the whole research I am disposed to consider the results given as true answers to questions truly put to nature. Whence then this apparent discrepancy between hypothesis and experiment? I believe the explanation is twofold.

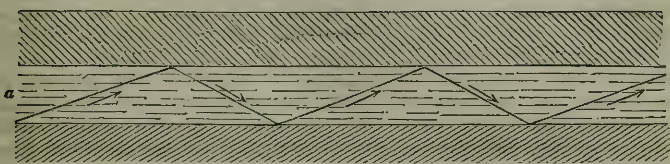
No such thing as an absolutely *solid and homogeneous* rock formation exists anywhere on the earth's surface. Whatever may be the rate of wave-transit in any one solid block or mass of rock, the transit rate through the whole depends not only upon the density and elasticity of the minerals, but upon the extent and degree to which its mass is broken and fissured, and upon the nature and direction of these fissures. If the fissures be but *fractures* with closely abutting surfaces, and these surfaces, chiefly either in planes perpendicular to, or in the direction of the wave's transit, they will produce the least degree of retardation in the velocity of the wave, and have the least effect in the extinction of its volume; but when such fissures are either alternations of bedding filled in with thick or thin layers of material, heterogeneous to the mass of the formation of invaded rock, or shatterings in various planes at many and uncertain angles of direction to that of the wave's motion, and with surfaces loosely approximating, or even altogether out of contact, then the effect, of loss of vis viva, at every such alternation of medium, in retarding the velocity of the wave, and by innumerable reflexions and alterations in direction, dispersing its volume, will be enormous.

In some instances, where the angle at which the new medium meets the line of transit of the emergent wave is suitable, reflexion (as in the case of

light) will no doubt be total, and thus an earthquake shock may emerge from the surface at a point totally different from that indicated by its original path.

An analogous phænomenon of continued reflexion seems to be the probable solution of the frequently-observed case of shocks felt in mines at certain depths, and yet not at the surface or still deeper in the mine. Thus, if *a*, *b* constitute a *couche* of formation of a certain elasticity and density, lying

Diag. 11.



upon another of very different and perhaps much lower elasticity, and with a third different formation superimposed, a wave transmitted at a certain angle in the direction of the arrow from *a*, may be reflected downwards and upwards alternately until extinguished, and while scarcely or not at all perceptible in the beds above or below, may produce a powerful shock throughout the intermediate beds *a*, *b*. The Saxon and South American mines afford frequent record of this phænomenon.

But to return. To these causes I ascribe the great deficiency in velocity which we have ascertained, below that due to the probable moduli of the materials. In the lower limit, the sand, which may be viewed as only the extreme case of a rock formation shattered and broken up indefinitely, the velocity due to its *material* would theoretically be the high one due to the highly elastic quartz of which its particles mainly consist; but the extreme want of continuity occurring at every fraction of an inch through which the path of the wave lies and the imperfect juxtaposition of the particles, neutralize all this; and the low conducting power of sand for impulse (elastic waves) is matter of even popular knowledge: thus we find sand-bags for this reason employed to form the breastworks of batteries, as the best material to absorb and neutralize the stroke of cannon-shot.

The retarding effects of heterogeneity of medium have been well shown by the results of Mr. Goldingham's elaborate experiments at Madras upon the rate of sound in dry and in damp air, from which he concluded that sound in common air suffered a retardation of 1·40 foot per second for each degree of his hygrometer, due to the admixture of moisture. If water in the state of intimate suspension, in which it exists invisibly dissolved in air, has such an effect, how much more might we look for it in sand mixed with air and water!

It would be premature and useless in the as yet imperfect state, both experimental and theoretic, of what we may hereafter call Stereo-acoustics, or knowledge of the nature of sound in solids, to affirm that these are *all the conditions* that may modify the transit rate of waves in such media, or that if we had presented to our experiments extended formations of mineral matter, absolutely homogeneous and unbroken, we then should find the transit rate of *longitudinal propagation* of the wave such as theory has hitherto predicted it, or that it would be the same as the transit rate of *free vibration* in the same medium. On the contrary, there is reason already to believe that hereafter it may prove to be otherwise.

We may recall the experiments made long since by M. Biot, upon the transit rate of sound in the cast iron water-pipes of Paris. He announced as his result that sound in cast iron travels longitudinally with a velocity 10·5

times that in air; but the velocity that would be deduced from the mean modulus of elasticity of cast iron gives 12·2 times that in air.

Much more recently MM. Wertheim and Breguet have made some most interesting experiments upon the rate of sound in malleable iron, namely, in the wires of the electric telegraph on the Versailles Railway, with a range of no less than 4050 metres. The method of experiment is remarkable for its simplicity and accuracy. It consisted in placing an observer and assistant at either end of the range, provided each with a chronometer, both of which were accurately rated together, and also with a delicate stop-watch, by which time could be noted to $\frac{1}{10}$th of a second. At a predetermined moment the observer struck a sharp blow of a hammer on the wire at one end; the assistant at the other noted the moment of arrival of the sound. This process was repeated back from the other end, and so on. Thus the personal errors, and those of the chronometers, became eliminated, and the length of range practically doubled.

Their results are, that sound travelled linearly in the wrought iron wire at the rate of only 3485 metres=11433·936 feet per second.

They then stretched two metres of the wire as a musical chord, and by Chladni's method determined the velocity of transversal vibration to be 4634 metres=15233·721 feet per second. Hence the experimental velocity of the sound-wave propagated longitudinally is much less than that of free or transversal vibration, and still less than that deducible from the mean modulus of wrought iron. The latter, however, would be abundantly uncertain in application, as the state of annealing of the wires, or their density, &c., are not given. (Comp. Rend. t. xxxii. p. 293.)

Should this indicate a general fact, as seems highly probable, then we have a theoretic cause, whose action coincides with that of want of homogeneity, in producing retardation of the elastic waves of our experiments.

In applying our results to any speculation as to the actual velocity of earthquake waves, the effects of the direction and depth from which they are propagated from the origin must be held in view.

As we descend deeper in every rocky formation of the earth's crust, we may expect to find the material not only denser (greater sp. gr.), but less and less shattered; and hence the velocity of the earth-wave will be greater in the same formation in proportion as its path lies deeper. When an emergent earth-wave reaches the surface, then its actual velocity, if transmitted from a great depth and at no very large angle from the vertical, may be very much greater than would be due to the surface rock; for theory at present does not admit of our determining how far into a second medium of lower elasticity the wave transmitted from another more elastic medium will penetrate the former with a velocity due to the first medium, or in what way and to what extent the velocity of the wave will be affected with reference to the distance traversed beyond the junction of the media; still less will theory yet enable us to predict the effects of gradual change of elastic coefficient of the medium through which the wave passes.

Again, if we assume the formation homogeneous in depth, and vibration propagated linearly in all directions alike from a centre of impulse; owing to the compression of the mass from the effects of gravitation thus acting at great depths, it is possible that the rate of wave transit may vary at different levels as some function of the depth, bearing an analogy to the case of a liquid confined in a tube, which Wertheim finds to transmit sound at a different rate (its transversal vibrations being confined) from a boundless mass of the same liquid. (Comp. Rend. t. xxviii. p. 151.)

The discussion of many earthquake narratives in the progress of the cata-

logue of the present Report, indicates that as a fact, earth-waves transmitted nearly vertically and hence probably from great depths, are most remarkable for the intense violence and velocity of the shock. Humboldt's account of the great earthquake at Riobamba (see preceding Report, and Humboldt's Personal Narrative), may be especially noticed in confirmation, where the velocity was stated to be such as to project the bodies of men and animals many feet into the air.

For this reason I have deemed it worth while to prepare a diagram, in which, taking the extreme horizontal or surface limits within which some of the greatest earthquakes on record have been observed to extend, and assuming that the emergent wave at each of those limits had no deeper origin than would be found by the chord of a great circle connecting them, which is certainly below the truth, I have endeavoured to show the depth within the earth's crust at which the origin might lie, equal in each case to the versed sine of the arc cut off. On this supposition the depth of origin of many of the great earthquakes may not have been very great (though it is likely in most of these cases the wave was an acutely emergent one over the whole area shaken); but in some others the depth of origin, even upon our most disadvantageous data, must have been very great; while in one extremely curious, though unfortunately doubtful case, there is some ground for believing that one and the same shock of earthquake was felt on Nov. 16, 1827, at places nearly antipodal, viz. at Ochotsk and at Columbia in South America; and, if so, had its origin not very remote from the centre of the earth.

Coincident earthquakes in time at very distant places on the earth's surface have been by no means rare, as at Iceland and Norway, Poland and Constantinople, &c. (See Catalogue.)

The preceding remarks as to the different velocity of the normal, and the transversal wave in elastic solids, suggest future inquiries of great interest and importance in relation to the so-often recorded double shock of earthquake. In frequently shaken regions popular belief attests the fact, that very soon after each shock another of less intensity and of a somewhat different character follows it, with however a very perceptible interval between, and which is fancied to be greater in proportion as the first shock is more powerful.

Admitting a sufficiently distant origin, the laws of normal and transversal vibration, as interpreted by Poisson *upon his hypothesis*, would be sufficient to account for the perception of a double blow; the probability of its arising truly from the successive emergence, first of the normal and then of the transversal wave, due to the one originating impulse, is rendered much greater on taking into consideration the facts above noticed, as ascertained by Wertheim and Breguet.

Another source of double shock is highly probable, but remains to be ascertained by further researches. In the more perfectly laminated and bedded slates, it is likely that both the normal and transversal waves will be divided, each into a pair having new paths of motion, each separating into what we may denominate *the ordinary* and *the extraordinary, normal* and *transversal waves*; the peculiar molecular arrangement of such rocks producing effects analogous to those of the ordinary and extraordinary rays of light in double refracting crystals.

Amongst the vast mass of recorded earthquakes that form the succeeding catalogue, it is to be regretted that not half-a-dozen out of nearly as many thousands, give any data by which the time of superficial transit of the shock in passing from one spot on the earth's surface to another could be ascertained. In a very few instances however sufficient data have been collected to ascer-

tain this in a rudely approximate way, and subject also to this additional source of error and uncertainty, that having no observation of the angle of emergence of the wave of shock at the place of observation (and indeed very seldom any apparent surface direction even given), and the apparent direction of shock being almost always very far from identical with its real direction, it becomes impossible to make the requisite trigonometrical allowance for the change, from apparent to true direction, in modifying the observed velocity, or rather the velocity as calculated, on the assumption that the wave traversed a great circle of the earth's surface between the two points at which the times of its transit had been observed; still it is of value to compare such rude approximations as we can yet command with the results we have already experimentally obtained. I proceed to do so.

In the Lisbon earthquake of 1761, the shock was recorded at the following times and places:—

H.M.S. Gosport off the Rock of Lisbon (given as lat. 44° 8′ N. and long. 5° 10′ W., apparently in error for 38° 4′ N. lat., 10° 5′ W. long.), shock felt at a quarter of an hour before noon.

At Corunna, felt at noon.

At Cork, felt at 12^h 15^m P.M.

At Santa Cruz, Barbary, at noon.

As all these places are nearly in the same longitude, the clocks require no correction for true time. The distances then are—

Lisbon Rock to Corunna .. 340 statute miles.
Lisbon Rock to Cork...... 903 „
Lisbon Rock to Santa Cruz . 556 „

or in time—

340 statute miles in $15^m = 22·66$ miles per minute.
903 .... $15^m = 60·0$ „
556 .... $15^m = 37·06$ „

The greatest of these transit rates occurs in a range under the Bay of Biscay, consisting probably to a great extent of hard consistent slates or other still more elastic rocks.

M. Perrey, in his Memoir on Earthquakes in the Antilles (Mem. Acad. de Dijon, 1845–46, p. 367), in recording the well-known shocks of Pointe à Pitre in Guadaloupe, of February 8, 1843, says, "M. Itier is of opinion that the shock in a direction from N.W. to S.E. took thirteen minutes to travel from Guadaloupe to Cayenne in South America. This distance is nearly 14° = 840 geographical = 973 statute miles, which is at the rate of 74·84 statute miles per minute."

M. Perrey attaches the greatest possible doubt to the correctness of M. Itier's records and observations in this matter. The superficial material forming the intermediate range is probably principally of soft diluvial or detrital material; but if the shock were transferred laterally, as is probable, at a great depth, and was felt transversal to its principal line of transit at Cayenne, it is likely to have had its range in very hard and elastic rock, though of what precise character there is no information.

The two following East Indian earthquakes are of much interest in reference to the point before us. The skeleton map of India (Pl. XVII.) I have prepared by reduction from Allen's great map, and approximately divided its surface into coloured geological divisions, having reference, not so much to recognised geological formations, as to the classification of formations together under one tint, that possess something like a general equality of probable transmissive power for earthquake-waves, so that the whole surface has been massed under six divisions, viz.—1, crystalline, schistose, or granitoid

rocks, coloured blue; 2, older stratified and carboniferous rocks, coloured dark gray; 3, secondary rocks, from carboniferous to cretaceous inclusive, coloured green; 4, the tertiary formations, coloured yellow; 5, alluvial plains, detritus, &c., coloured brown; and 6, igneous rocks, modern porphyries, diorites, &c., coloured red. The data have been principally derived from Johnston's 'Physical Atlas,' and no attempt at exact definition of boundary has been attempted, the object in view being to give some notion of the class of formations through which the ranges of the shocks now about being mentioned lay.

The places at which the shocks were felt and recorded are marked along with some of the greater physical features of the country, and the observed directions of the shocks are marked by arrows.

The first Indian earthquake referred to is that of June 16, 1819, the night on which Cutch was wholly destroyed, the Run of Cutch submerged, and the great Ullah Bund (a vast elevated bank of sand and slob) thrown up; there were two great shocks, which were felt more or less almost over all Central India.

On the same night, with the same interval of two minutes between them, two slight shocks were felt at Calcutta upon the opposite side of that great continent, where they were sufficient to cause suspended lamps, &c. to vibrate. These, there can be no rational doubt, were due to the same original impulse that produced such devastation at Cutch more than 1000 miles off.

They were observed at Calcutta at half-past eight o'clock, which is 90 minutes later than the great shocks were noted at Cutch. The distance on a great circle is about 1200 statute miles, which reduced gives a transit rate of only 13·33 miles per minute (Roy. As. Journn. vol. ix. p. 70).

A considerable distance at both extremities of this long range consists of loose diluvial material of the lowest possible transit coefficient, but a large portion of the central tract traversed appears to consist of formations possessing a much higher elasticity.

On the 26th of August, 1834, the great earthquake of Nepaul occurred, which convulsed the whole of that region, and was felt throughout the Punjaub and over a large part of central India. No important information has been obtained as to its phænomena nearer to its probable origin, which appears to have been somewhere in Thibet or Lassa, to the north and east of the Himalayan chain. The Journ. Roy. As. Soc. vol. xiii. p. 158, contains a summary of the events as experienced in Nepaul, where it seems to have been very formidable. The direction there generally appeared to be from N.E. to S.W.

The principal shocks were at 6 o'clock P.M.; half-past 6 o'clock; half-past 11 o'clock; and 55 minutes past noon, all Calcutta time; and vibrations were almost continuous the whole day (24 hours) of the 26th of August, 1834; in 1829 such vibrations continued for 40 days or more.

Dr. Campbell, at Katmandu, says, "The shock at 6 o'clock lasted about 40 seconds; its sound was like that of heavy ordnance passing over a drawbridge rapidly." "I felt that it was travelling with the speed of lightning towards the west and just under my feet;" "trees waved to the roots as it passed." Dr. C. was at the time at his house on the hills, about a mile away from Katmandu, the capital of Nepaul; and at the coming on of the third shock, the murmured prayers of the vast multitude in the city reached his ear with a terrible sublimity like the voice of many waters; above 100 houses were levelled there in a moment. All the shocks seemed to come from the E. and N.E.

Places to the east of Katmandu suffered still more; at Bhatgaun 1000

houses were levelled and 300 people killed, with 500 persons more in the valley. "At Monghyr, Rungpur, Mozufferpur, Mallai, all in the direct line of influence, many houses have been destroyed."

At Calcutta three shocks were felt. Hanging lamps were moved, but no damage was done. At Agra the shocks were rapid and strong, lasting a few seconds each. At Lucknow four shocks were perceived; "the tremulous motion was like that of a steam vessel" (probably meaning that tremulous motion sometimes produced by the draft of the steam-boiler fires), the beams creaked and cornices fell down.

At Tyrhut the movement was from E. to W.; water in a tank 4 feet deep, whose surface was 3 feet below the edge or brim of the tank, was thrown out.

At Purneah the shock was the severest ever felt there; houses were thrown down, birds flew frightened from their roosts, sleeping horses were wakened and rose in alarm, an astronomical clock was stopped; and from observations on it and some other circumstances, it was concluded that the shock there came from the south, and travelled east (a very singular and sudden change of purpose if it were so).

At Buxar the direction was apparently from N. to S; it is added, "the motion seemed a good deal bounded by the Ganges, as at Koruntadhee; just opposite to Buxar much less motion was felt than on the right bank of the river." At Monghyr seven distinct shocks were felt between 5 and half-past 8 o'clock A.M. of the 27th of August, and there had been more than 25 felt during the night.

At Patna, at 30 minutes past eleven P.M. of the 26th of August, a great shock was felt from east to west, and another at midnight; eighteen shocks were counted by some observers.

All the country about Bankipoor, Dinapore, Diggah, &c. was shaken.

These rather incoherent accounts must serve to give some general notion of the power and extent of this earthquake. The precise moment of the occurrence of the second shock was noted at Calcutta by its stopping an astronomical clock. The moment of shock at several other distant places was also noted and the observed time corrected, for Calcutta time, as referred to this particular clock.

The following is a list of those places and the times of shock corrected for longitude:—

Place.	Lat. N.	Long. E.	Observed Time and Correction.	Calcutta Time.
	° ′	°	h ′ ′	h ′ ″
Calcutta	22 36	88 24	....	11 34 48
Katmandu	27 43	85 13	11 45 + 12	10 57
Rungpur	25 43	89 22	11 20 − 2	11 18
Monghyr	25 22	86 29	11 27 + 7	11 34
Arrah	25 35	84 40	11 15 + 14	11 29
Rotas Hills	32 58	73 41	11 10 + 20	11 30
Gorackpur	26 44	83 18	11 20 + 19	11 39
Allahabad	25 26	81 48	11 0 + 28	11 28
Bankura*......	24 90	77 90	11 30 + 4	11 34
Tyrhoot	?	?	Time not correctly observed.	
Buxar	25 32	83 55	Ditto.	
Patna	25 35	85 90	Ditto.	

* Quære Rampoora.

From the extremely conflicting or imperfect accounts given, as to the directions in which the shocks were observed, and hence the uncertainty as to what places may be taken as extremes of each range, I am only able from the above list to select four cases in which we can arrive at any conclusion worthy of reliance as to the approximate rate of transit of this shock. These are—

Rungpur to Arrah, 290 statute miles, in 11 minutes = 26·363 miles per minute.

Monghyr to Gorackpur, 200 statute miles in 5 minutes = 40 miles per minute: this was in granite a part of the way.

Rungpur to Monghyr, 180 miles in 16 minutes = 11·25 statute miles per minute.

Rungpur to Calcutta, 220 miles in 16 minutes = 13·75 statute miles per minute: this was chiefly in low alluvial deposits.

The last instance I shall at present advert to is that of two ships at sea, both of which experienced a shock within half-an-hour; it has been pointed out to me by my respected friend Dr. Robinson as noticed in the Nautical Magazine for March 1851, p. 165. Lieut. Maury, of the National Observatory at Washington, in noticing the existence of a submarine volcano, as observed by Captain Ballard of the ship Rambler, from Calcutta, on the 30th of October, in lat. 16° 30′ N., long. 54° 30′ W., and Captain Potter of the barque Millwood, last from Rio, half-an-hour later on the same day, when in lat. 23° 30′ N. and long. 58° 0′ W., remarks, "These vessels were about 520 miles apart; supposing them in the direct line in which the earthquake was travelling, its rate will appear to be about 1 mile in 5 seconds, which is only a little slower than sound (at the rate of 1 mile in 4·6 seconds) travels through air."

It is possible there may have been two shocks, and that each ship's company felt a separate one; but this is very improbable; for as the ships were only 520 miles apart, had there been, each vessel could scarcely have escaped being sensible of two shocks; assuming then it to have been a single earthquake, the rate is 520 miles in 30 minutes, or only 17·3 miles per minute. In this case it is probable that the shock traversed (*quam prox.*) horizontally beds of loose material of vast depth at the bottom of the sea, and that the shock thence was conveyed transversely upwards through the water to the ships.

In the following Table I have placed together the results of all the preceding data as to the approximate rates of earthquake waves from observation. The value of this at present is simply that it affords strong presumptive confirmation of the correctness of the results of the preceding experiments, and that both make it almost certain that the actual rate of transit of earthquake-waves, when hereafter there shall be the means of their perfect observation, as occurring in nature, will be found very much slower indeed than I myself and others anticipated on theoretic grounds, based on the elastic moduli of the rocky crust, *considered as everywhere an unbroken elastic solid.* But as giving yet awhile correct ideas of the actual rates, the following Table must be received as but most rudely approximate.

With the exception of the Guadaloupe earthquake, upon which much doubt rests, the greatest rate of transit in the foregoing Table falls greatly below what would have been anticipated, on the assumption of the wave passing through perfectly solid elastic bodies, while the general character of the rates coordinate pretty well with the limits experimentally given in the preceding pages.

Table No. 8.

Probable Transit Rates of Earthquake Waves, as observed and calculated, from various authorities.

Occasion and Place.	Approximate rate in feet per second.	Formation constituting range on surface so far as known or conjectured.	Authority.
Rev. John Mitchell's guesses, from the Lisbon earthquakes	1760	Sea-bottom, probably on slates, secondary and crystalline rocks.	Mitchell.
Von Humboldt's ditto, from South American	from 1760 to 2464	From observations in various South American rocks, in great part volcanic	Humboldt.
Lisbon Earthquake of 1761.			
Lisbon to Corunna	1994	Transition, carboniferous and granitoid	Annual Register.
Lisbon to Cork	5228	Transition, carboniferous, crystalline slates and granitoid, probably, under the sea-bottom.	Annual Register.
Lisbon to Santa Cruz	3261	The same with many alternations	Annual Register.
Antilles.			
Pointe à Pitre to Cayenne (doubtful)	6586	Probably volcanic rocks under sea-bottom	Itier & Perrey, Mem. Dijon.
India.			
Cutch to Calcutta (1819)	1173	Alluvial, secondary, granitoid, and later igneous rocks	Royal Asiat. Journ.
India.—Nepaul and Basin of the Ganges (1834).			
Rungpur to Arrah	2314	Deep alluvia, with occasional transition, carboniferous, granitoid, and later igneous rocks.	Royal Asiat. Journ.
Monghyr to Gorackpur	3520		
Rungpur to Monghyr	990		
Rungpur to Calcutta	1210		
Ships Rambler and Millwood at Sea (1851).			
Between lat. 16° 30′ N. long., 54° 30′ W., and lat. 23° 30′ N., long. 58° 0′ W.	1056	Sea-bottom resting on unknown rock	Nautical Magazine.

It seems highly probable that future instrumental determinations of the rates of natural earthquake-waves will show that—

1. In cases where the line of movement of the wave is not far from vertical, occurring in hard crystalline and very solid rock of one sort, and having an origin at a considerable depth, the rate of wave transit will approximate nearly to that of a normal wave due to the modulus of the formation, the rate of the wave being also probably affected by the limits of the mass in which it moves.

2. That in every superficial rock formation, as being all more or less shattered and none homogeneous, and in any given extensive range several different formations intervening, the rate of transit will be found probably seldom or never to approach the preceding velocity.

3. While in discontinuous media, such as sand, gravel, diluvial clays, mud, &c., the rate of transit will be the slowest of all, although for reasons given in the former Report, the destructive effects of the wave in such materials may be greater than in any other.

It follows, from the conclusions that we have so far arrived at, that while

experiments in the closet to ascertain the moduli of elasticity of various rocks or other mineral masses cannot but be of great interest and value to science, they will be of less direct importance to seismology than was at first anticipated, and that no determinations of the transit rate of earthquake waves can be made in a trustworthy manner, except—1st, by multiplying experiments in various rocks or discontinuous formations of different degrees of heterogeneity and homogeneity, by the method described in the preceding pages, by that of MM. Wertheim and Breguet, which is applicable in some instances with great advantage and convenience, or by some other which may be devised; and 2nd, by actual instrumental determinations of the rate of earthquake-waves as they occur in nature: this can only be done by self-registering instruments such as that at present attempted to be constructed.

It is scarcely necessary further to revert to the deep interest that attaches to such researches, affording, as they do, the most direct and likely means of acquiring some information as to the—

1. Depth below the surface of the great seats of volcanic action, and their identity or not, in position and nature, with the great forces of elevation.
2. Depth of the solid crust of the earth.
3. Nature of the great oceanic beds.

To the following gentlemen my especial thanks are due for aid rendered to me and to my son William, who assisted throughout in these experiments. To Sir John F. Burgoyne, K.C.B., the Master-General, and the respective Officers of Ordnance; to Dr. Robinson, for the kindest interest and encouragement and much valuable suggestion and information; to Professor Wheatstone, for the use of his chronograph and communication of his experience as to the best modes of bringing it into use; to the Directors of the Dublin and Kingstown Railway, for the use of the telegraph wires at Dalkey; and their officer Mr. Bergin, for the loan of his galvanic batteries; to Professor Downing, for aid in the admeasurement of the first base line; and to Barry D. Gibbons, Esq., C.E. and M. B. Mullins, Esq., Contractor of Kingstown Harbour, for assistance in the operations upon the granite; with others, whose assistance, if less defined, was highly important.

I now proceed to the *EARTHQUAKE CATALOGUE*, and the results obtained by its discussion.

Of the Construction of the Catalogue.

Former partial catalogues, more especially those of Von Hoff, Cotte, Hoffman, Merian, and Perrey, have formed the basis of the present, as I believe first attempt, to complete a catalogue that shall embrace all recorded earthquakes. By the first and last of the preceding authors our labours have been most lightened. In Von Hoff's Catalogue (Gesch. d. Veränd. &c. vol. iii.) a total break occurs from the year 1806 to 1820 inclusive, and it ends with 1832. M. Perrey's numerous and valuable local catalogues are scattered through various foreign journals; he has latterly produced and still continues to publish a current annual catalogue, for which he is anxious to receive contributions from observers of intelligence situated in all parts of the world, addressed to him at Dijon. Besides the above and some minor catalogues, our work has been compiled from multitudes of scattered sources, collected in foreign and in British libraries, the accessions from which have at least amounted to as much as from all prior catalogues.

Notwithstanding much labour and time, it is not for a moment to be assumed that the present catalogue is complete, that it embraces *all* known records of earthquakes; such a work would probably be impracticable; in

any case it would involve the associated labour of several persons for many years to produce. But the number of instances now catalogued is so large, and the mode of collection and arrangement such, that I believe science would derive no very material or proportionate advantage from the bestowal of much more time and labour to increase it.

The *base of induction* now produced embraces between 5000 and 6000 separate earthquakes, and as this is the main use of an extended catalogue, if that number be deemed sufficient, the object is answered, although some or even many recorded earthquakes within our period had remained unadded to the list. That some might be so added I doubt not. It is possible that many trustworthy records of these events exist in Russia, as respects the north-west of North America and Northern Asia. In Central and Northern India such may also be found; while there is little doubt that in the ancient libraries of the Levantine monasteries, and in those of Spain and Portugal, a rich mine of such information remains yet unexplored, to which we had no access. For other portions of the inhabited earth's surface, records are almost or altogether wanting. Of these the most important and interesting are, Madagascar, and the interior, indeed the whole, of Africa including Abyssinia, except its northern coast and the Cape of Good Hope, Greenland and Labrador, Northern and Eastern Asia, Northern Australia, and the Pacific Islands generally.

The constructors of former catalogues have usually been at no pains to make any systematic arrangement of their materials; each is a mere chronicle of events, in partial sequence of date, but otherwise mixed with such disregard of order or relative importance, that reference to any special class of phænomena, except by exhausting it from the mass by reading it all through, was impossible.

The succeeding catalogue aims at a tabular arrangement, in which the more important elements of earthquake facts are placed in separate columns for each instance, and thus reference facilitated. The catalogue is divided into six columns, embracing—

1. The date and time, as nearly as recorded.
2. The locality or place of occurrence.
3. The direction, duration, and number of shocks in each case, so far as these are recorded.
4. Phænomena connected with the sea; great sea or other waves, tides, &c.
5. Phænomena belonging to the land; meteorological phænomena preceding and succeeding, and all secondary phænomena. This embraces all those minor although occasionally important facts, that are mixed in earthquake narratives with the principal facts, which we might call the "elements of the earthquake," as here comprised in our first three columns.
6. The authority for the record.

Many of the dates in the earliest periods of the catalogue and up to about A.D. 1000, are extremely doubtful; on collating separate authorities for the same earthquake, even at much later periods, and in cases of occurrences the most remarkable, and one would suppose well known, the discrepancies that are found are marvellous.

The dates of the eighteenth century have not been attempted to be altered to new or old style, but in each case, as far as possible, the style (old or new) as mentioned by the original author is given; very many of the dates are given however by narrators of this period without any intimation of whether they refer to old or new style.

The time of day is not often given in a reliable form. In times and coun-

tries under the Romish church it is often given in such vague form as "at vespers," "after the morning mass," &c.

The locality is the recorded place of occurrence, but it is obvious that in most cases many other places were also more or less entitled to be recorded as shaken; the place set down however has been, in the vast majority of instances, either the most violently affected, or one of them; and, at least in the absence of better information, must be viewed, unless otherwise stated, as about the centre of disturbance.

The direction, duration, and number of shocks, are seldom given; the scanty records of those most important elements best show how much we must expect yet from future observations aided by instruments. Duration also is often given in the middle ages in a strange and loose form, as in such phrases as "during one Credo," or "while saying the Ave."

In recording the phænomena belonging to the sea and to the land deemed worthy of notice, it may be remarked—

Effects (secondary phænomena) are only given, either as measures of the violence of the shock, or as presenting some fact likely to be of importance in earthquake dynamics.

All phænomena recorded as having *possibly* been due to earthquakes, of which there are many, even in the catalogues of Von Hoff and Perrey, such as landslips, abnormal tides, &c., are omitted, unless there exist some good reason (such as an earthquake occurring at the same or nearly the time in some other part of the world) to suppose a real connection with seismic causes. And in selecting the phænomena recorded, choice has been made of those of most scientific importance, rather than those most curious to the mere general reader.

Wherever opportunity was had of consulting the original author or authors, it has been endeavoured not to mention subsequently as an authority any mere copyist from such original. It is to be regretted that in some other catalogues this has not been attended to, and hence an event often appears to be supported by a number of independent authorities, that, upon research, all resolve themselves into copiers from one amongst them. Where there are various accounts of the same event by different authors, attention has been directed in choosing amongst them; first of all, to the proximity of the recorder both in time and in place, to the event, taking also into account the general standard of authority or credibility of his works, as far as known to us, and also the number of independent concurrent testimonies to the event in more important cases. Where, as is often the case in older records, the same historian is quoted indifferently under two or more names, one name or title has been adhered to invariably. For example, Abulfaradsch and Bar Hebræus are two names for the same historian used indifferently by Von Hoff.

Some of the very early authors, such as Julius Obsequens, and many of those about the decline of the eastern empire, appear, at least as regards our subject, of very doubtful authority, and it is scarcely necessary to say that the same remark may apply to many records of Chinese and Japanese earthquakes. The records multiply in number and increase in accuracy and authority as we pass down the stream of time; and within the last 200 years is embraced a mass of earthquake incident, probably from these causes, equal in scientific value to the whole of the preceding parts of the catalogue.

The influence of commerce and navigation in modern times upon observational science, and of the disenthralment of mankind, in Europe at least, from much of the superstition and tyranny of the middle ages, could scarcely

be more strikingly shown than by the curves produced from the discussion of the present catalogue referred to hereafter.

Where the volume and page of an author are not quoted, the event will be found in its chronological order in the note referred to.

Where access to the original work has been impossible, and we have merely quoted from some other compiler or narrator, we are only responsible for having accurately transcribed; our experience seems to show that other transcribers have usually been very accurate.

In the characteristic expressions used in the fourth and fifth columns, and transcribed from other authors, they must be taken with reference to *degree*, as only giving the author's own opinion of the fact, whatever it may be, and such expressions are often extremely difficult, either to attach a true value to or compare together. Thus such phrases as "violent," "very violent," depend much for their import upon where and by whom they were used. An earthquake described as "very violent" by an inhabitant of Norway or of Great Britain, might seem but a very slight and insignificant affair to a dweller at Lima or Quito, though both were equally discreet and trustworthy observers.

There has been also experienced much difficulty in some cases of long-continued vibratory jars at a given locality, such as those of Bâle, East Haddam and Comrie, &c., in deciding whether one such epoch was to be recognised as one earthquake, or as more than one.

Any further observations however will be best reserved for the conclusion of the catalogue, when referring to the discussion by curves of the distribution of earthquakes in time, and by the large map of their distribution in space.

Letter from Professor Henry, *Secretary of the Smithsonian Institution at Washington, to* Colonel Sabine, *General Secretary of the British Association, on the System of Meteorological Observations proposed to be established in the United States.*

Smithsonian Institution,
Washington, March 22, 1851.

Dear Sir,—The meteorological system in the process of being established in the United States, is intended to embrace as far as possible the whole area of the North American continent, including the Isthmus of Central America, the West India Islands, Bermuda, and Newfoundland.

It is to consist of three classes of observers:—

I. Those without instruments, to record—

1. The changes in the aspect of the sky.
2. The direction and approximate force of the wind and the time of its changes.
3. The beginning and ending of rain, snow, &c.
4. The appearance of the Aurora Borealis.
5. The time and direction of approach, and other phænomena of thunder-storms.
6. The registration of phænomena relative to plants and animals, such as the first appearance of leaves and of flowers in plants; the dates of appearance and disappearance of migratory or hybernating animals, as Mammalia, Birds, Reptiles, Fishes, Insects, &c.; the times of nesting of Birds, of moulting, and littering of

Mammalia, of utterance of characteristic cries among Reptiles and Insects, and anything else which may be deemed noteworthy.

II. To record, in addition to the foregoing, the changes of atmospheric temperature as indicated by a standard thermometer.

III. This class to be furnished with a full set of instruments for recording all the changes deemed important in the study of meteorology, exclusive of magnetism.

To carry on this system, the Institution has received, or expects to receive, cooperation from the following resources :—

1. From the small appropriation made by Congress to be expended under the direction of this Institution and the Navy department conjointly.

2. From the appropriations made by different States of the Union.

3. From the observations made under the direction of the Medical department of the U.S. Army.

4. From observations made by institutions and individuals on different parts of the Continent, who report immediately to the Smithsonian Institution.

5. From officers of Her Britannic Majesty's Service in different parts of the British Possessions in North America.

The following is an account of what has been actually accomplished, extracted from the last Report of the Regents of the Smithsonian Institution to Congress.

"A small appropriation has been made by Congress for two years past, to be expended under the direction of the Navy department, for meteorological purposes, and Professor Espy, engaged under the Act authorizing this appropriation, has been directed to cooperate with the Institution in the promotion of the common object. Besides the aid which we have received from the knowledge of Professor Espy on this subject, the general system has been benefited from that source by the use of instruments purchased by the surplus of the appropriation, after paying the salary of Professor Espy, and other expenses.

"During the last year Mr. Espy has been engaged in a series of interesting and valuable experiments on the change of temperature produced by a sudden change in the density of the air. The results which he has obtained are interesting to science in general, and directly applicable to meteorology.

"These experiments were all made in one of the rooms of the Smithsonian Institution, and with articles of apparatus belonging to the collection which constituted the liberal donation of Dr. Hare of Philadelphia. An account of these experiments will be given to the Secretary of the Navy in Mr. Espy's report.

"It was mentioned in the last report, that the regents of the University of the State of New York in 1849, made a liberal appropriation of funds for the reorganization of the meteorological system of observations established in 1825, and that Dr. T. Romeyn Beck, and the Hon. Gideon Hawley, to whom the enterprise was entrusted, had adopted the instruments prepared under the direction of the Smithsonian Institution. Another appropriation has been made for 1850, and the system has been carried during the last year into successful operation by Professor Guyot, late of Neufchatel in Switzerland. This gentleman, who has established a wide reputation as a meteorological observer by his labours in his own country, was recommended to Dr. Beck and Mr. Hawley by this Institution, and employed by them to superintend the fitting up of the instruments, to instruct the observers in the minute details of their duty, and to determine the topographical character, and elevation above the sea, of each station.

"The whole number of stations which have been established in the State

of New York is thirty-eight, including those which have been furnished with instruments by the Smithsonian Institution, and the Adirondac station by the liberality of Archibald M'Intyre Esq. of Albany. This number gives one station to 1270 square miles, or about one in each square of about $35\frac{1}{2}$ miles on a side. These stations are at very different heights from the level of the sea, up to 2000 feet. They were selected in conference with Dr. Beck, Professor Guyot, and myself. The State is naturally divided into the following topographical regions, namely :—

"1. Southern, or maritime region.

"2. Eastern, or region of the Highlands, and Catskill mountains, with the valleys of the Hudson and Mohawk rivers.

"3. The northern, or region of the Adirondac mountains, isolated by the deep valleys of the Mohawk, Lake Champlain, St. Lawrence, and Lake Ontario.

"4. The western, or region of the western plateau, with the small lakes, and sources of the rivers.

"5. The regions of the great Lakes Erie and Ontario.

"We regret to state that no efficient steps have as yet been taken to organize the system of Massachusetts, for which an appropriation was made by the legislature at its last session. I have lately written to Governor Briggs urging immediate action, and offering on the part of the Institution to render any assistance in our power towards furthering so laudable an enterprise. No answer has yet been received*.

"The observations made at the different military stations, under the direction of the Medical department of the U.S. Army, have been partially reorganized, and a number of new stations, and several of the old ones, furnished with the improved instruments made under the direction of this institution.

"The head of the Medical department of the Army, Dr. Lawson, has assigned the general direction of the system of observations to Dr. Morrer of New York, to whom we are indebted for the valuable aid which this extended set of observations will furnish the general system. The immediate superintendence of the reduction of these observations is in charge of Dr. A. S. Wotherspoon, U.S.A., to whose zeal and scientific abilities the cause of meteorology bids fair to be much indebted.

"The most important service the Smithsonian Institution has rendered to meteorology during the past year, has been the general introduction into the country of a more accurate set of instruments at a reasonable price. It has been enabled to effect this through the aid of Professor Guyot. The set consists of a barometer, thermometer, hygrometer, wind-vane, and snow and rain-gauge.

"The barometer is made by James Green, No. 422 Broadway, New York, under the direction of the Institution. It has a glass cistern, with an adjustable bottom enclosed in a brass cylinder. The barometer tube is also enclosed in a brass cylinder which carries the Vernier ; the whole is suspended freely from a ring at the top, so as to adjust itself to the vertical position. The bulb of the attached thermometer is inclosed in a brass envelope, communicating with the interior of the brass tube, so as to be in the same condition with the mercury, and to indicate truly its temperature. Each instrument made according to this pattern is numbered and accurately compared with a standard. In the comparisons made by Professor Guyot, a standard Fortin barometer,

* Since the above was written, a communication has been received from the Governor of Massachusetts, placing the organization of its system of meteorology under the direction of the Smithsonian Institution.

made by Ernst of Paris, was used, and also a standard English barometer by Newman of London, belonging to this Institution. These instruments, for greater certainty, have been compared with the standard of Cambridge Observatory, and of Columbia College, both by Newman, and with the standard of the observatory of Toronto, Canada West. The results of these examinations prove the barometers made by Mr. Green, according to the plan adopted by the Smithsonian Institution, to be trustworthy instruments. The thermometers are by the same maker, and those intended for the State of New York were compared with a standard by Bunten of Paris, and another by Troughton and Simms of London. Those found to differ more than a given quantity from the standard were rejected.

"The instruments for detecting the variation of the hygrometrical condition of the atmosphere consists of two thermometers of the same dimensions accurately graduated. The bulb of one of these is enveloped in a covering of muslin and moistened with water, and that of the other is naked.

"The rain and snow-gauges, and also the wind-vanes, are made under the direction of this Institution by Messrs. Benj. Pike and Son, 166 Broadway, New York. The rain-gauge is an inverted cone of sheet zinc, of which the area of the base is exactly 100 square inches. This cone or funnel terminates in a tube which carries the water into a receiving vessel until the end of the rain. The water which has fallen is measured by pouring it into a cylinder so graduated as to indicate hundredths of inches of rain. A smaller cylinder is also provided which gives the thousandths of inches of rain, and may serve in case of accident as a substitute for the larger cylinder. The rain-gauge is placed in a cask sunk in the earth with its mouth near the level of the ground.

"The-snow gauge is a cylinder of zinc of the same diameter as the mouth of the rain-gauge. The measurement is made by pressing it mouth downward to the bottom of the snow where it has fallen on a level surface, and then carefully inverting it, retaining the snow by passing under it a thin plate of metal. The snow is afterwards melted, and the water produced is measured in one of the glass graduated cylinders of the rain-gauge.

"The wind-vane is a thin sheet of metal (it might be of wood) about three feet long, carefully balanced by a ball of lead, and supported on the top of a long wooden rod, which descends along the wall of the building to the sill of the window of the observer. It terminates in the centre of a fixed dial plate, and indicates in its movements the direction of the wind by a pointer attached to the rod.

"The observer is by this arrangement enabled to determine the course of the wind by looking down on the dial plate through the glass of the window, without exposing himself to the storm.

"Besides the full sets of instruments furnished by the State of New York from the appropriation of the Regents of the University, the Smithsonian Institution has furnished a number of sets to important stations; and in order that the instruments may be more widely disseminated, have directed Mr. Green to dispose of sets to individuals at a reduced price, on condition that they will give copies of the results of their observations; the remainder of their cost being paid by this Institution. A number of persons have availed themselves of this privilege.

"To accompany the instruments, and for the use of those who take part in the Smithsonian system of meteorological observations, a series of minute directions, prepared by Professor Guyot, has been printed by us, occupying forty octavo pages, with woodcut representations of the instruments. This is accompanied by two lithographic engravings to illustrate the different

forms of clouds and to facilitate their notation on the journal, in accordance with the nomenclature adopted by meteorologists.

"The following collection of tables, to be used in reducing the observations, has been prepared by Professor Guyot at the expense of the Institution:—

Thermometrical Tables.
Barometrical „
Hygrometrical „
Hypsometrical „

" Besides these it is proposed to furnish a set of tables for determining heights by means of the barometer. We may also mention, in connexion with this subject, that a series of preliminary experiments have been made in the laboratory of this Institution for the purpose of constructing from direct observation a scale of boiling temperatures corresponding to different degrees of rarefaction of the air. With a thermometer, each degree of which occupies one inch in length of the scale, the variations of the boiling corresponding to a slight change in altitude are found to be more perceptible than those of variations in altitude of the barometrical column. A series of experiments has also been made for testing the performance of the aneroid barometer under extremes of atmospheric pressure. The instrument, however, has not been found from these experiments very reliable, though it may serve as a baryscope or an indicator of atmospheric changes. It will by no means serve for the determination of atmospheric pressure, particularly when subjected to ranges of considerable magnitude.

" For the better comprehension of the relative position of the several places of observation now embraced in our system of meteorology, an outline map of North America has been constructed by Dr. Foreman. This map is intended also to be used for presenting the successive phases of the sky over the whole country as far as reported to us at different epochs, and we have been waiting for its completion by the engraver to commence a series of investigations with the materials now on hand relative to the progress of storms.

" A valuable collection of returns relative to the aurora has been received in accordance with the special instructions which we have issued for the observation of this interesting phænomenon. These are to be placed in the hands of Capt. Lefroy of the Toronto Observatory, and incorporated with observations of a similar kind which he has collected in the British Possessions of North America. Abstracts of the whole series will be presented by Capt. Lefroy, to be published in the Smithsonian 'Contributions to Knowledge.'

" The whole number of observers on which we may now depend, including those of all classes, is about 200; these are, however, very irregularly distributed over the face of the country. By far the greater number are in New York and New England. We hope, however, to be enabled to enlist a number of other States, and to carry out the plan more efficiently in behalf of the Institution as soon as our income will warrant a larger expenditure of means for this purpose.

" The number of stations must be left to yourself*, and their distribution had best be determined by consultation with Capt. Lefroy. I would, how-

* [This paragraph was written in the belief entertained at the time by Professor Henry, that the cooperation of the British Government would be asked to carry this system of observation over the whole of the North American Continent, by establishing corresponding stations in the British portion. It appears, however, by subsequent communications, that this request has been made, not to the British Government, but to the Governor of the Canadian Provinces.]—E. S., March 1852.

ever, remark, that since it has been found that the winter storms travel eastward, it would be well to have some observers in Nova Scotia, Labrador and Newfoundland. One at St. John's, Newfoundland, would be desirable. As to the time of commencing, we can scarcely perhaps secure a perfect organization prior to the beginning of 1853.

"I remain, very respectfully, your friend and servant,

"JOSEPH HENRY, *Secretary.*"

Col. E. Sabine.

Report on the Kew Magnetographs. By Colonel SABINE, *R.A.*

AT the request of the Council Colonel Sabine gave a brief account of the experimental trial now making at the Kew Observatory of Mr. Ronalds's Instruments for the self-registry of the Variations of Terrestrial Magnetism by means of Photography.

The general principle of these instruments and their mechanical details have been already described at former Meetings, and have been printed in the Reports of the Association. But until instruments have been tested by actual performance, no certain opinion of their fitness for the purposes for which they were designed can be confidently pronounced; and the superintending Committee at Kew have for some time past felt a rather anxious desire, that the preparation of these instruments should reach the stage at which a fair practical trial might be made of their efficiency, as a means of recording the magnetic phænomena in any part of the world where science might require that they should be known. Before this could be done however,—before a correct estimate could be formed of the degree in which they might be useful, either as auxiliaries, or as superseding the method of *observation* previously in use, it was necessary that *three* instruments should be provided, one for the variations of the declination, and two for those of the horizontal and vertical components of the force. From the limited funds which the British Association has had it in its power to appropriate to the furtherance of the objects of the Kew Observatory, it had been just barely possible to complete two of the three instruments between the years 1846 and 1850, and the third must yet have been waited for, had not a resource presented itself in the Government grant in 1850 placed at the disposal of the President and Council of the Royal Society, to be applied in aiding the progress of the experimental sciences. A portion of this grant was obtained, and the three instruments being at length by its aid completed, Mr. Ronalds, with the sanction of the superintending Committee, proposed to the Council of the Royal Society that the instruments should be subjected to an experimental trial by being worked precisely as in an observatory, for a period of six months (that period being considered as likely to be sufficient for a due appreciation of their merits or deficiencies in reference to the present requirements of magnetical science); and that every item of expense incurred in carrying on the self-registry for that period should be carefully noted and stated. This proposition having been approved by the Council of the Royal Society, a grant of £100, for the purpose of carrying it into execution, was made to Mr. Ronalds from the donation fund, the property of the Royal Society. The six months' trial commenced in April last, and a full account of its results will be presented to the Royal Society; meantime the Council of the British Association have deemed that a brief account of the nature of the trial might not be unacceptable to its members.

The magnetic variations are recorded by Mr. Ronalds's instruments either on silvered plates or on prepared paper. The silvered plates are supposed to have the advantages of greater sensibility to the impressions of light, and of requiring in consequence a less time of exposure to the light, so that movements of a more rapid character or of more transient duration may be recorded by them;—and also of producing more sharply defined traces, and of being free from the defects occasioned by the inequalities of surface to which paper is subject, and by those caused by the stretching and shrinking of paper when moistened and when dry. The paper, on the other hand, is supposed to have an advantage in the circumstance that the actual traces themselves can be preserved, whereas the preservation of the original traces made on the plates would be out of the question on account of the expense, except on very particular occasions. Towards a just appreciation of the preference due to the plates or to the paper in this application of Photometry, it is necessary to take into the account the practical purposes for which the record is obtained and has to be employed. The mere inspection of the trace, as shown either on the plate or on paper, no doubt, possesses an interest both to the uninstructed and to those more familiar with the magnetic phænomena; and it may be, that amidst the great variety of those phænomena there may be some which may have light thrown upon them by peculiarities only discoverable by a very close examination of the trace itself. But as in astronomy the advancement of the science has more particularly followed from the combination of *measuring apparatus* with optical power, so in terrestrial magnetism the analysis of the various periodical and other causes, which in their joint action produce the *variations* which the photographical traces record, requires that the traces should undergo *tabulation* as a preliminary step to their practical application; arrangements for rapid and exact tabulation are therefore as necessary as the photographic means of making a trace*.

Mr. Ronalds has adopted for the trial which is now in progress the plan, which as far as can be judged at present appears the most advantageous, of taking the traces on *plates*, from which they are tabulated with great accuracy and with tolerable rapidity by the aid of ingeniously contrived apparatus, and when the tabulation is completed the traces themselves are copied by the hand with a graver's tool on transparent gelatine paper, an operation which requires about a quarter of an hour for each trace of twenty-four hours, and can be done after a little practice with very considerable accuracy. The copies thus made are arranged in a journal and preserved. The gelatine paper, which is of French manufacture, but is easily obtained in London, is found to answer extremely well for the purpose, is durable, and bears handling well; so well indeed that impressions are freely taken on this paper by means of printer's ink and a small press, from the copies of the trace on gelatine paper employed as if it were a metal plate. These impressions are useful to send by post on days of unusual disturbance to other observatories.

* In the application to Government made in 1845 by the President of the British Association (Sir John Herschel) to "encourage by specific pecuniary rewards the improvement of self-recording magnetic and meteorological instruments," the following were stated as the reasons which had induced the British Association to direct the application to be made:—

1. "The great ultimate saving of time and expense which would take place in observatories established for the purpose of magnetical and meteorological determinations, if such apparatus were improved to a degree admitting its indications to be confidently trusted in the absence of an observer, and *recorded in a manner suitable for scientific use.*

2. "The advantages which would accrue to those sciences from continuous registry of their phænomena, instead of observations taken, as at present, at intervals of time."

The tabulation is a far more serious matter as regards the time consumed in the operation. Where traces vary from day to day so much as magnetic traces are liable to do, the time required in tabulation must also be liable to vary considerably; but it is found on a general average by Mr. Welsh, to whose able and careful management Mr. Ronalds has confided this department of the experimental trial, that the trace of each instrument in twenty-four hours takes about three-quarters of an hour to measure and tabulate, both sides of the trace being measured, and a mean taken between them. The extent to which tabulation is carried is so calculated as to meet the various inquiries for which it is likely to be required, and generally speaking to reproduce the trace, though not of course perfectly in all cases. When the processes of tabulation and copying are completed, the plate is cleaned and is ready to be used again.

Taking into account the labour of the photographist and that of the person charged with the operations that have been just described, the work of a photographical magnetic observatory in the present state of the apparatus can by no means be deemed light; but it has the advantage, and it is a great one, of producing a continuous record.

The plates are prepared and changed once in every twenty-four hours; the length of the plate is twelve inches, and as this corresponds to the time-scale, which is an inch an hour, each plate is inverted at the expiration of twelve hours, and thus at the expiration of the twenty-four hours each plate is charged with a double trace, each trace having also its attendant zero line. The width of the plates employed at Kew is three inches, being deemed a fair ordinary width. In parts of the globe where great disturbances prevail, and where at the same time great precision is required in the variations of small amount, a larger field than that of three inches may be desirable, and may be given, but for moderate variations three inches seems an ample field. It has been found by the concurrent experience of several persons that the traces on the plates can be read off with full confidence to the 500th of an inch; consequently the three-inch plate gives a scale of 1500 distinctly recognizable parts. Taking the Declinometer as an example which will be most generally understood, if a single division of the scale is made equal to six seconds, the range of the scale will extend to $1500 \times 6 = 9000$ seconds, or $2^\circ\ 30'$.

Mr. Ronalds's instruments have a great advantage in the general stability and freedom from shake of the apparatus; all parts which have a reference to each other are bound together with marble and metal, the only wood employed being used strictly for exterior casing only. They have also a great advantage in the constancy of the zero line, which is assured by mechanical contrivance. The zero line has thus a permanent absolute magnetic value, which remains unchanged from day to day, as well as at all times of the same day.

The time of exposure to the light by which each part of the trace has been formed is one minute and a half. It is probable that by improvements in photographical preparations the trace may hereafter be formed by an exposure of much less duration, and that the length of the magnets, which is now twelve or fifteen inches, may also be greatly reduced. Both these improvements appear to be required if we desire that the trace should individualize perturbations succeeding each other with great rapidity. If Mr. Ronalds should succeed in substituting for the silvered plates a less costly material, on which the traces might be taken with equal sharpness, and with equal or greater rapidity, the photographic part of his invention would seem to need scarcely any further improvement.—*July* 1851.

Report to Francis Ronalds, *Esq., on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory, April* 1 *till October* 1, 1851. *By* John Welsh, Esq.

In making a preliminary report on the performance of the three Magnetographs during the experimental trial of them which has just expired, I shall confine myself to a statement of—1st, the methods adopted for adjustment of the several instruments; 2nd, the means of preserving a record, numerical and graphical, of the photographic registers; and 3rd, the general capabilities of the instruments of affording data for magnetical investigation. The instruments having been already minutely described in your various reports on the Observatory, it is unnecessary to make any reference to their mechanical construction.

I. Adjustments, &c.

Declination Magnetograph.—This instrument was put into adjustment on March 27–29. The suspending thread, of untwisted silk, was examined throughout its whole extent, and found to have retained its original condition. The magnet having been removed, a brass bar of the same weight was inserted in its place, and the amount of torsion existing in the thread examined. This amounted to only 10° and was eliminated.

The value in arc corresponding to a given ordinate on the registering plate depends upon,—first, the distance from the centre of motion of the magnet and its appendages to the slit in the moveable shield; and second, the number of times by which the image of a certain motion of the slit is magnified when represented upon the registering plate. The first of these is obtained by direct measurement with a beam compass; for the determination of the second, the following contrivance was resorted to:—A scale divided on plane glass to $\frac{1}{50}$th of an inch was placed in such a position that the lines of the graduation were at the same distance from the lens as the slit in the moveable shield when the magnet is in full adjustment. A scale of the same value divided on ground glass was placed in the sliding plate-frame, and upon it the magnified image of the first scale was received at the proper focus. Both the scales were in this way visible on the same surface: the one magnified, and the other of the natural size. It was then easy to observe the value of the one in terms of the other; the number of divisions of the *real* scale corresponding to one division of the *apparent* scale representing the magnifying power of the lens. If a be the required arc value corresponding to an ordinate d on the plate, r the distance of the slit from the centre of motion of the magnet, and m the magnifying power of the lens, we have $a=\tan^{-1}\frac{d}{m.r}$, or when the angular motions are small, $a=\text{arc}^{-1}\frac{d}{m.r}$ very nearly. The value of r was found by measurement to be 18·0 inches; and that of m, by the process above-described, 6·706; whence we have the arc-value of an ordinate of one inch$=28'\cdot48$.

By turning the arms of the torsion-circle through different angles, it was found that a twist of 90° in the thread deflected the magnet through 44′; whence the value of the torsion coefficient $\left(1+\frac{\text{H}}{\text{F}}\right)=1\cdot008$.

This torsion effect being taken into account, the arc-value of one inch $=28'\cdot71$. The scale employed in the process of tabulation being divided to $\frac{1}{50}$th of an inch, the factor for converting the recorded numbers into minutes of arc is $0'\cdot574$.

The same observations which determine the magnifying power of the lens, afford also a means of estimating the amount of its spherical aberration. For this purpose we have merely to examine whether the value of the *apparent* scale in terms of the *real* scale remains constant at different portions of the field. Observations of this kind having been made for all the instruments, there is no reason to believe that, within the adopted range of motion, any irregularity of scale exists. The scale divided on ground glass, which is fixed permanently in each of the sliding plate-frames, supplies a means of observing the positions of the magnets when the photographic registration is not in action, and has been found of essential service in the preliminary adjustments of the instruments. The scales are of the same value as that employed in tabulating the numerical results: the zero division of the scale can also be adjusted to correspond with the edge of the spot of light which gives the zero-line on the plate; observations taken in this way are therefore at once comparable with the photographic measurements.

The length of time during which the light is allowed to act upon the plate when the instrument is in action, is found by measuring the width of the diaphragm at the image end of the camera; or more accurately by measuring the length of the impression produced by the light from the moveable slit when the plate is at rest. This was found to correspond to about $6\frac{1}{2}$ minutes.

The series of registrations by this instrument has been on several occasions interrupted by derangements in the adjustments: these have been shown in alterations of the relative positions of the fixed and moveable shields. The moveable shield ought always to overlap, by a small quantity, the fixed one, so as to stop all light except such as passes through the slits. It has several times occurred that the shields have become so far separated as to allow the light to spread across the plate and thus to prevent the appearance of the curves. At other times the contrary has happened, the moveable shield so much overlapping the fixed one as to obliterate the light from the slit which produces the zero-line, the curve line being however still recorded. On one occasion, about the end of July, it was found that the fixed shield had become too high relatively to the image-diaphragm. For some days previous to this being discovered, the registers were very faint, owing to the great loss of light arising from this cause. These errors were always removed by opening up the instrument and readjusting the parts deranged—an operation which always renders doubtful the connexion between the observations before and after the adjustments. The derangements now stated have been ascribed to alterations in the condition of the wooden supports of the instrument, arising from changes of temperature or humidity. They may also be partly owing to the expansion and contraction of the very long suspending string.

Horizontal-Force Magnetograph.—The value in arc of the ordinates for this instrument was found in the manner already described for the declination. The radius of the moveable shield $=9{\cdot}08$ inches, and the magnifying power of the lens $=3{\cdot}46$; whence the arc-value of $\frac{1}{50}$th of an inch$=2'{\cdot}188$. The arc-value was also determined on September 20th, 1850, by a different process, as follows. The magnet having been removed, an equal weight was suspended from the stirrup. There being then no magnetic directive force, and the torsion-force of the bifilar suspension being considerable, when the arms of the torsion-circle are turned through any angle, the arm carrying the shield should move through the same angle. The image of the slit being observed upon a divided scale placed at the focus, its motions corresponding to certain changes of the circle reading were observed. From the mean of

several observations it was found that the ordinate of $\frac{1}{50}$th of an inch $=2'{\cdot}192$, agreeing very closely with the value obtained by the other method. The optical value for $\frac{1}{50}$th of an inch$=2'{\cdot}19$.

The value of the angle of torsion of the suspending wires was determined by a method quite similar to that described in the 'Report of the Committee of the Royal Society.' The arm carrying the moveable shield has a motion in azimuth similar to that of the collimator in Dr. Lloyd's form of the bifilar magnetometer; the position of the image of the slit, with reference to the divisions of the ground-glass scale, serving all the purposes of the telescope and scale. The angle of torsion in the present adjustment was found to be $64° 45'$. By the usual formula, we find the value, in parts of the whole horizontal force, of an ordinate of $\frac{1}{50}$th of an inch$=0{\cdot}000300$.

The effect of temperature upon the magnetic moment of the bar was examined in December 1850 by the usual method of deflections. The results were—At temperature $55°{\cdot}3$, the effect of one degree$=0{\cdot}000312$; and at temperature $76°{\cdot}7$, the effect of one degree$=0{\cdot}000344$.

The temperature of the magnet is obtained by a thermometer whose bulb is within the box. Observations of the thermometer were taken generally every three hours, rather more frequently during the day, and not so often at night. They were taken usually by myself during the day and until midnight; whilst Mr. Nicklin, whom I had instructed so as to observe the thermometer with accuracy, took them at early morning or during my occasional absence.

The effect of the illuminating lamp in heating the air within the magnet box has been found to be rather considerable. At the commencement of the series, when no precautions had been adopted to prevent this effect, the thermometer showed that the air was heated about 4 or 5 degrees above what it would have been had the lamp been away; wooden screens were afterwards interposed for the purpose of preventing radiation from the lamp, but the effect was still about 2 or $2\frac{1}{2}$ degrees.

The effect of the new copper damper in checking mechanical oscillation was found to be very striking, a large arc of vibration being reduced to nothing in four or five swings.

The length of time during which the light of the registering image acts upon the plate is about $1\frac{3}{4}$ minute.

Vertical-Force Magnetograph.—The agate planes, upon which the knife-edges of the magnet rest, were made horizontal by means of a level supplied for the purpose by Mr. Barrow, and the instrument brought into approximate adjustment. The distance from the centre of motion (the knife-edge) to that portion of the slit in the moveable shield which produces the image on the plate, was thus obtained:—a brass rod carrying a shield, with a slit similar to that attached to the magnet, was made to rest, in an upright position, upon the agate planes, by means of a cross piece having a flat base which occupied the same position as the knife-edge of the magnet when in adjustment. The image of a portion of the slit is formed upon the focus glass: a fine point was then moved slowly along the slit by one person until another observed the image of the slit bisected by that of the point. A mark was there made on the shield. The distance of this point from the base is equal to the distance from the centre of motion to the effective portion of the slit in the moveable shield, and may readily be determined by a scale and square. It was found to be 11·93 inches. The magnifying power of the lens was found by the method already described to be 3·78. From these quantities we have the value in arc corresponding to an ordinate of $\frac{1}{50}$th of an inch$=1'{\cdot}525$.

The coefficient, for converting the angular motions of the magnet into variations of the whole vertical force, has been obtained by the usual method of vibration in the horizontal and vertical planes. The magnet, with its appendages, having been first brought into approximate adjustment, was removed and slung horizontally by a slight loop of thread attached to a silk suspension. It was defended from currents of air by being enclosed in a cylindrical box with lids, the thread being alone exposed. A microscope with cross wires was fixed to one side of this box, and so adjusted that a mark on the shield carried by the magnet was visible. A vibration of about 2° was given to the magnet, and the times of transit of the mark across the wire noted by a chronometer. On March 31st the time of one oscillation was found to be 17·90 seconds, the temperature being 52°. The time of vibration in the vertical plane was observed by watching the motion of the image on the ground-glass scale, the initial arc being generally nearly 2°.

Owing to the arrangement of the stone pier upon which the apparatus rests, and the position of the window from which light was obtained, the magnet could not be conveniently mounted either in the magnetic meridian or at right angles to it. It was in fact mounted at right angles to the astronomical meridian, the north end being directed to about 67° west of the magnetic north. The mode of adjusting the horizontality of the magnet was the same as in Dr. Lloyd's original balance-magnets, namely, a screw attached near the south end working horizontally.

The adjustment for the height of the centre of gravity was effected at first by altering the position of the weight which counterpoises the vertical arm carrying the moveable shield. After August 8th this adjustment was made by a screw working vertically in the same frame as the horizontal adjusting screw, the former method having been found very inconvenient.

In the beginning of August, the instrument, having been for some weeks performing very indifferently, was returned to Mr. Barrow for alteration. He stated that the knife-edges had become much deteriorated and even somewhat rusted; they were therefore re-ground: he was desired at the same time to alter the mode of adjusting for the position of the centre of gravity. The counterpoise weight below was permanently fixed; and a screw working vertically attached to the south end, an equal weight being added at the north end. On the magnet being returned it was again vibrated horizontally; and the time of one oscillation found to be 18·52 seconds, the temperature being 72°.

The temperature correction for this magnet was determined at the same time as that for the horizontal force. The results were—At temperature 50°·4, the effect of one degree=0·000283; at temperature 71°·5, the effect of one degree=0·000319.

The thermometer for this instrument was observed at the same time as that of the horizontal force. The effect of the lamp in heating the air in the magnet box was very trifling.

Several circumstances have tended to prevent the satisfactory performance of this instrument. When it was first put into action, the marble slab which carries the magnet and its supports was *suspended* from the upper slab, upon which were placed the camera, the lens, and the clock apparatus. This upper slab again was merely *laid* upon the corbel supports, and not fastened down to them. It was almost constantly noticed, during the month of April, that the photographic trace exhibited sudden breaks or dislocations in the curve, accompanied by oscillation of the magnet. These breaks could nearly always be referred to periods when something was done in connexion with the instrument, especially about sunset and sunrise, when the lamp was placed

or removed; and also at noon and midnight, when the registering plates were changed or reversed. It having been noticed on one or two occasions with certainty, that a disturbance of the magnet occurred at the times of changing the plates, it was conjectured that these anomalous motions might be due to concussions generated in the apparatus by the necessary manipulations, and that those at sunset and sunrise might arise from a similar cause. In the end of April the instrument was fixed more securely to its supports. The four brass columns which connected the lower slab to the upper were removed, and the slab cemented to an additional massive corbel: the upper slab was at the same time cemented to its supporting corbels. Care was taken to preserve as nearly as possible the previous relative positions of the different parts. The effect of this change was at once to remove the disturbances which had occurred about noon and midnight; those at the placing and removal of the lamp, however, still remained. Whilst making a more careful trial, as to whether there was any magnetic action connected with the lamp, the real cause of this particular class of disturbance occurred to me; and in a few minutes it was traced to the different positions of the iron bars of the window-shutters, when these were closed or opened. It had, in fact, been remarked previously, that the disturbances at sunrise and sunset occurred always in opposite directions. This source of error having been discovered, it was remedied by the immediate removal of all the shutter-bars to the basement story. These anomalous dislocations in the curves were after this time scarcely ever experienced.

Other errors have exhibited themselves, the causes of which we have not yet discovered; one of these is,—a tendency of the magnet to change its mean position from day to day, and always in one direction, showing an apparent gradual diminution of the vertical force. This change has generally been to an extent which quite precludes the idea of its being due, either to a real magnetic change, or to a loss of magnetism in the needle. That the latter is not the cause, we have only to refer to the two observations of the time of oscillation in the horizontal plane given above: from these we see that, considering the higher temperature at the time of the second observation, and the fact that an additional weight had in the interim been put on the magnet, the loss of magnetism has been trifling.

Another, and perhaps a more serious error is the inconstancy of the height of the centre of gravity, as shown by variation of the time of vibration in a vertical plane. In nearly every case of adjustment during the six months, it has been found that, after some days, the time of one vibration has diminished to a very large extent. The following are a few of the cases in which this has been shown:—

April 1.	At adjustment, the time of vibration was			20 secs.
... 29.	28 days after,	...	...	11 ...
May 5.	At adjustment,	...	...	25 ...
June 4.	30 days after,	...	...	13 ...
... 5.	At adjustment,	...	...	25 ...
... 20.	15 days after,	...	...	17 ...
... 26.	At adjustment,	...	...	$23\frac{1}{2}$ ...
July 11.	15 days after,	...	...	11 ...

Again, the knife-edges having been in the interim re-ground:—

Aug. 14.	At adjustment, the time of vibration was			23·1 secs.
... 25.	11 days after,	...	...	22·4 ...
Sept. 9.	26 days after,	...	...	16·2 ...

Very remarkable changes of this nature have been previously observed in

balance-magnets, but in no case that I am aware of, has the variation been to such an extent as is shown above. Observations have been taken of the time of vibration for different inclinations of the magnet, with the view of ascertaining whether this diminution could be owing to variations in the bearing-points of the knife-edges. These differences have in some cases been considerable, but not nearly so great as to account for such excessive changes. I cannot venture as yet to give any opinion as to the probable cause. With the occasionally excellent performance of the magnet (as shown, for example, in the magnetic disturbance of Sept. 3–4) before us, it is difficult to conceive that it can be wholly due to imperfection of the knife-edges *.

II. Tabulation of Numerical Results, &c.

In preserving a numerical record of the changes as shown by the magnetographs, the objects kept in view have been,—1st, to obtain data for deducing mean results, such as the diurnal changes, daily and monthly means, &c.; 2nd, to record all the changes which can be said to come under the class of disturbances; and 3rd, generally, to possess in a numerical form, as far as is practicable, the means of producing the complete curves, either as originally recorded photographically, or in the true form of declination, inclination, and total magnetic force.

The positions of all the magnets have been measured for every hour of Greenwich time during which we have had records; in almost all cases the position for each half-hour has also been noted. Whenever the fluctuation has been at all marked, the turning-points of the fluctuation with the corresponding epochs have been measured; very few motions exceeding two scale divisions will be found omitted. Attention has been paid, as far as possible, to have simultaneous measurements of all the instruments, but especially of the two components of force. Both edges of the photographic trace have always been measured, and the mean of the two entered; by this means the effects of mechanical oscillation and of variable breadth of the trace from whatever cause, are eliminated. The number of measurements for each instrument during twenty-four hours has of course varied very much; it may be said, however, that the lowest number is 48, whilst in some cases of great disturbance as many as 150 measurements have been taken; the average is probably somewhat more than 60. Any unusual appearance in the curves, such as small and rapid fluctuation with little change of mean position, has been mentioned. The attempt has been made throughout to leave no phænomenon of any consequence unrepresented.

In taking these measurements, the edge of the scale is brought very near to the surface of the plate, in order, as much as possible, to prevent error from parallax; a compound magnifying lens with a flat field being used in reading off. From my own experience, supported by the opinions of several gentlemen accustomed to observation, I estimate the accuracy with which the better defined traces can be measured at about $\frac{1}{500}$th of an inch, or one-tenth of a division of the measuring scale. In the case of the declination, the trace not being so distinct, probably $\frac{1}{250}$th of an inch should be considered as the extent of accuracy. These estimates give for the probable error of a measurement of the declination about $0'{\cdot}1$, and for the horizontal force about 0·00003 of the whole force. The adjustments of the vertical force in-

* Shortly after the date of this report it was discovered that a spot of rust had formed upon one of the knife-edges: this had not been perceived when the magnet was examined about the beginning of October; although it may have been already in operation, but to so small an extent as to be imperceptible to the eye. It seems highly probable that a considerable share of the irregularities complained of may be ascribed to this cause.

strument having been so variable, no constant estimate can be given for it; in an average adjustment, however, it is believed that the probable error of a measurement will not exceed 0·000015 of the whole vertical force.

Failures in the registration have been mentioned whenever they have occurred, and a note taken of the cause when such is known. On examination of these records, I find that, in the case of the declination, there are about seventy-five hours in the six months during which no registrations have been obtained, owing to insufficiency of the photographic process; in the horizontal force there are about fifty hours. No failures whatever have taken place in the photographic process during the last ten weeks of the trial. Failures have occasionally occurred from causes purely accidental, such as omitting to wind the clocks, not properly adjusting the sliding plate-frames, forgetting to open the valve of the declination lamp, and such like. These, however, must be considered rather as personal than instrumental errors.

All the photographic registrations have been copied upon gelatine tracing-paper. I am not yet prepared to give any estimate as to the accuracy with which these copies are made.

III. General Remarks on the Capabilities of the Instruments.

In forming an opinion as to the powers of the instruments, it is necessary to take into consideration the circumstances connected with their construction. The declination magnetograph was the first instrument constructed according to your design, and consequently cannot be expected to equal in accuracy or convenience those afterwards made. From the essential portions of its structure being altogether of wood, it would be too much to expect from it a long-continued series of trustworthy records, where steadiness and permanency of adjustment are so necessary. The large dimensions of the magnet and its appendages would, on any system of observation, present great difficulties whenever the more rapid magnetic changes occur. A considerable loss of light is sustained by the position of the instrument requiring the daylight to be reflected, and the photographic difficulties are accordingly increased. The want of a copper damper sufficiently powerful to eliminate the mechanical oscillation of the magnet, by permitting an almost continuous minute vibration, tends to diminish the sharpness of outline in the trace. It has accordingly been found that, owing to changes taking place in the framework of the apparatus, a series of more than a few weeks cannot be obtained without some slight adjustments of the instrument. When the magnetic changes become very rapid and extensive, it fails to afford all the information which is desirable. Instances of failure in this respect will be found in some of the larger disturbances which have occurred during the trial, as, for example, in those of the 3rd and 29th of September, when, from the excessive abruptness of the magnetic motions, and the want of delicacy in what may be styled the registering-pencil, the interpretation of the photographic records becomes very difficult and uncertain. Notwithstanding the defects which I have alluded to, it is, however, certain that the instrument is capable of affording a large amount of information. It exhibits with much exactness all the common fluctuations; and there can be no doubt that very trustworthy results, as to the mean diurnal movements, could be obtained from it. Even disturbances of considerable amount, especially those which, although of large extent, are not of an abrupt character, are recorded with as much accuracy as seems to be desirable. In short, the instrument, even in its present state, is capable of providing a very great porportion of the data required for magnetical investigation.

In the horizontal-force magnetograph, the defects of construction in the

declination have been in a great degree remedied. All the essential parts of the apparatus being of metal or stone, the permanency of the adjustments is secured. The light being admitted directly to the instrument, and the optical power not being so great, the photographic means are increased. The dimensions of the magnet and its appendages being much smaller, the mechanical inertia is diminished; and by the use of a very powerful copper damper, the inconvenience arising from vibration is almost wholly got rid of. The results of these improvements are such as might be expected. It has been found that a long series of registrations can be obtained without the occurrence of a single case of mechanical derangement requiring re-adjustment of any portion of the apparatus. The instrument has been found capable of recording, in a perfectly distinct manner, almost all the magnetic changes which occur, and with a delicacy of scale quite sufficient to represent even the most minute movement. In only one instance during the six months has it been unable to overtake the most rapid motions. In the disturbance of September 29, it certainly has been found deficient in power to represent with distinctness those very violent and extensive changes which occasionally do occur. This deficiency seems to have arisen—1st, from the length of time during which the plate is exposed to the action of the light being sufficient for more than one motion to take place; and 2nd, from the mechanical inertia being still so great, as in some instances to carry the magnet farther in the direction of a sudden magnetic change than is strictly due to such change. These defects seem to point to the desirability of further improvements in the same direction as those already made, namely, greater photographic power and less mechanical inertia. It should be remarked also, that in the larger disturbances the extent of scale adopted for all the instruments has been insufficient to contain the extreme excursions.

The performance of the vertical force instrument has unfortunately been so little satisfactory, from causes apparently unconnected with the means necessary to adapt it to photographic registration, that it is impossible to come to a distinct conclusion as to its value. Its performance for some time after being repaired by the maker was, however, so good, and its power of exhibiting such great and sudden motions as occurred during the disturbance of September 3–4 so considerable, as to hold out the expectation that, whenever the source of the errors already noticed shall have been discovered, it may be found to be a really efficient and trustworthy instrument.

John Welsh.

Kew Observatory, October 23, 1851.

Report concerning the Observatory of the British Association at Kew, from August 1, 1850 *to July* 1, 1851. *By* Francis Ronalds, *Esq., F.R.S., Honorary Superintendent.*

It is hoped that this eighth annual summary relative to the status and proceedings of the Kew Observatory will evince our sincere desire to promote the liberal views of the British Association, and that our diligence has been commensurate with the augmented funds which have been kindly granted by Her Majesty's Government and the Royal Society, and with the increased interest which gentlemen of the highest scientific acquirements and reputation, both at home and abroad, have manifested in the success of the Establishment.

The principal means which I have employed in its composition have been references to my former Reports of a like kind; examinations of the various instruments, &c. spoken of; descriptions, &c. from my own portfolios; the Electro-meteorological Journal; the tabulations and tracings of the magnetic curves, &c., and the Kew Diary.

The materials which I have used for supplying some omissions in our Diary have been three manuscripts concerning the Meteorological Journal, the Barometrograph, and the Hygrometers, drawn up by Mr. Welsh (our observer). In making use of the Diary and all other documents, endeavours have constantly been made to record shortly only such facts as may be, or may become useful, and to do this in the words themselves of those documents whenever a due regard to brevity permitted.

The subjects are arranged under four heads:—1st, those which relate to the Building, Instruments, &c.; 2ndly, those referable to the Observations; 3rdly, experimental (and analogous) subjects; and lastly, those which do not properly belong to any of the former.

I. THE BUILDING, INSTRUMENTS, &c.

*The edifice** has undergone no change of importance this year. The annexation of three new corbels to the wall of the great mural quadrant, for the support of a new Vertical-force Magnetograph, is probably a temporary expedient. The custody of a large quantity of apparatus, consigned to our care by the Royal Society, and of which a portion is highly valued, from the circumstances of its having been invented, or made, or even possessed by such men as Boyle, Huygens, Newton, Cook, Cavendish, Coulomb, Le Roy, Sabine, Kater, &c., renders a little reparation (of damage by dry rot) and painting very desirable (a long time has elapsed since any interior painting has been done); and it has frequently been thought advisable that the wall of the great quadrant, which instrument has long since been dismantled, and will never be again employed, should be converted into piers, pedestals, &c. for the support of experimental instruments requiring scrupulous regard to immutability of position and exemption from extraneous vibration†.

In speaking of the Instruments, I refer principally to those which have been more or less used in this year.

Electrical Apparatus.

The Principal Conductor, &c. on, and in, the Dome, and all the electrical apparatus which has been employed for the observations of atmospheric electricity, are in working order. The *Rod*, *Lantern*, &c., the *Volta-Electrometers*, *Henley-Electrometer*, *Discharger* and *Distinguisher*, retain the forms described at p. 123 (*et seq.*) of the Report for 1844. The *Observer's Clock and its scale* remain as described at p. 178 of the Report for 1850.

The Galvanometer of M. Goujon gives strong indications when connected with the conductor, in times of violent rain, &c., but is not to be depended upon as to measures.

* Described at p. 120, Report for 1844.

† Two of the magnetographs, although solidly, are inconveniently placed. The photo-barometrograph requires a much better foundation than boards and joists can afford (as will be seen); and for the due prosecution of projected observations of standard and other barometers, pendulums, &c., extremely solid bases cannot (obviously) be dispensed with.

The three Night-Registering Electrometers, described at p. 139 of the Report for 1844, are effective, but little employed. They were very useful formerly, but will soon give place to the Photo-Electrograph.

The Gold-leaf Electroscope itself remains nearly as described at p. 125 of the same volume. The little additional apparatus for preserving its insulating power, afterwards alluded to, and now described more particularly, has been found very convenient and effective.

A (Plate XVIII. fig. 2) is a thick plate of well-ground and polished glass.

B, a kind of annular tin trough, coated with sealing-wax varnish, and containing chloride of calcium.

C, the electroscope.

On the central part of A, not occupied by B, stands C; which, together with B, is covered by a glass receiver, fitting air-tight upon A when C is not in use.

By this means the electroscope may be preserved in a dry and clean state, and quite ready for use at any moment; and it is evident that a similar drying arrangement may be adopted in respect of a Volta, or any other detached electrometer or electrical instrument, &c.

The pair of *Portable Volta-Electrometers*, occasionally used on the leaden roof of the building for experiments on induction, absorption, &c. of atmospheric electricity, are in the original state alluded to at p. 140 of the Report for 1844; they were not particularly described there, because, with the exception of a few additions and alterations, they are similar to the instruments used in the dome; but several eminent meteorologists having thought that these instruments would, if used with proper precautions, afford better approximative results in observations, on mountains, &c., than the portable instruments which have been usually employed, the following short but complete account of them may possibly be found convenient.

A (Plate XVIII. fig. 1) is the lower part of one of them.

a^1, a little hollow pedestal, the side, base, and upper surface of which are formed out of one brass casting. It is about 3 inches high and 2 inches square.

a^2, a cupola of cast brass screwed firmly into its upper surface.

a^3, a lamina of thin plate-glass polished and attached, by a frame of brass and screws, to a^2: a lamina of *ground* glass is fixed in like manner to the back of a^1.

a^4, a tube of thick glass well-coated with shell-lac, applied by heating the glass until it is capable of melting the lac, but not of carbonizing it. It passes through and is firmly cemented to a cover which is screwed into a^2. Its lower end projects about an inch below the cover, and on the upper end is cemented a brass cap and screw. A wire, forming a continuation of that screw, passes through the bore of a^4, in which it is securely fixed; this wire terminates below in a flattened part, which has two minute perforations at the distance of half a Paris line from each other.

a^5, a pair of Volta's straw *penduletti*, two Paris inches long. In their upper ends are fixed hooks of fine copper wire, which pass through the perforations and suspend the straws freely: their lengths and diameters are in strict conformity with Volta's prescription for his standard instrument (No. 1).

a^6, an ivory scale fixed in front of a^3; its upper edge is an arc whose radius is equal to the lengths of a^5, and it is graduated in half Paris lines;

the zero-point being opposite to the line where the straws nearly touch each other when unelectrified.

a^7 is a small brass tube or cap fitted upon the cap of a^4, but whose interior cylindrical surface stands at the distance of about $\frac{1}{10}$th of an inch from the coating of lac on a^4; it can be removed at pleasure*.

B is an electrometer, similar to A in all respects, excepting as regards its pair of straws b^5, which are rendered so much heavier than the straws of A, by filling their cavities with the prolonged wire of their hooks, as to diverge (when both are equally electrified) exactly $\frac{1}{5}$th as much. This arrangement agrees with Volta's prescription for his electrometer No. 2, and the exact accordance of the two instruments is ascertained by his halving process†.

C is the conductor, consisting of a very light conical tube of copper about 3 feet 6 inches long, and furnished with a brass cap below, which screws upon the cap of a^4.

c^1 (fig. 1^a) is a helix of small copper wire, the lower and smaller part of which fits upon the upper extremity of C; the upper part being considerably larger.

c^2, a *solfanello* (of Volta), *i. e.* a sulphur candle, composed of about 10 threads of lamp-cotton coated and imbued with sulphur whilst in a melted state. It is placed in the larger part of c^1.

D is a mahogany case placed upon a portable staff or table, or a post.

d^1 d^1, &c. grooved pieces, between which the lower parts of A and B may be slid, and the instruments be thus properly packed for transport.

d^2, a little drawer containing a supply of *solfanelli*, &c.

A hollow walking-cane may contain C, disjointed for the sake of portability; and tubes might be occasionally slid through the bottoms of a^1 and b^1 to embrace a^5 and b^5, thus preventing their violent vibration, &c. in transport.

When these instruments are to be used in Volta's or Bennet's manner, c^1 may be slid upon C, and c^2 (lighted) into c^1; when in Saussure's manner, a pointed wire may be substituted for c^1 and c^2; when in Cavallo's, Erman's, or Peltier's (inductive) manner, a ball may be attached to the end of C, or C may be disjointed and a ball attached to its lower joint; or the instrument may be used without any such conductor, as may be most suitable to circumstances of locality, &c.

In all cases where the atmospheric charge is not extremely minute, straws are infinitely preferable to gold leaves, which can never be safely transported in their instrument.

The *Peltier Electrometer*, or (rather) Erman's, which has been particularly described by both inventors, can scarcely be said to be in working order, its insulating capacity having greatly diminished.

Electrical Observatory for transport.—The expense and difficulty of conveying to distant stations apparatus for electrical observations so large and heavy as is ours, have furnished the motives for arranging some instruments, already existing at Kew in the form represented by fig. 3, Plate XVIII., which shows that a very efficient apparatus may be constructed at small comparative expense, and presenting considerable facility of transport.

The round-house AA is drawn in half-section; its proportions are derived from a square portable house which came to Kew from Woolwich for some

* Since the above was written, an electrometer of this kind has been presented to Lieut. Cheyne for employment in Sir Edward Belcher's north polar expedition.

† Vide Opere del Volta, tome i. parte ii. p. 13 *et seq.*

proposed magnetic vibration experiments; it is high enough to allow an observer to stand in it, and broad enough to allow him to view the electrometers in a stooping attitude. Several parts of the contained apparatus are similar to the principal corresponding parts in our Dome (vide Report for 1844, p.120). Some are improved.

a is a mahogany varnished cylinder fitted into a circular aperture in the roof, and furnished with a smooth ring or rim projecting outward from the upper end.

B, a window (which may serve for photographic purposes, &c.).

C, my strong hexapod-stand; but capable of being folded into a very small compass*.

c^1, a safety conductor of thick copper wire, in good conducting communication, with moist earth or water.

D, fig. 3^a, is the upper end of the principal conductor, which is a light conical tube of copper 12 feet long.

E, a brass tube whose upper end is $2\frac{1}{2}$ feet above the roof of A, and into which the lower end of D is firmly screwed, but from which it can be removed at pleasure by a person standing on the roof of A.

F, the usual stout hollow glass pillar, with its collar of wood, &c. It is trumpet-shaped below and firmly secured by bolts passing through the collar and table.

G, the table, which also carries the other instruments.

H, the cap with a globular ring fitted on F, and supporting

II, which are two conical tubular arms of brass.

KK, the bolts, &c. which contain the screws, plugs, and stoppers for sustaining and adjusting the sliding arms, &c.

k^1 k^1, the clamping balls.

k^2, one of the sliding arms passing through K, &c. and adjustable vertically (or to any angle). It can be secured in any required position by means of k^1, in the manner formerly described.

L, the small warming lamp.

l^1, the usual conical chimney of copper, closed above and entering F, to which it imparts warmth from L.

M, fig. 3^a, a small Volta's lantern, fitted by a socket on the top of D. It contains the collecting lamp, and is provided with a little cowl† in lieu of the former perforated cap.

N, a copper cylindrical parapluie, fitted by a collar on E, and having a smooth ring or rim, projecting nearly as much inward as the rim of a^1 projects outward‡.

O, the uninsulated part of Volta's standard or electrometer No. 1.

P, his second electrometer, both as improved and formerly described.

QQ, the usual apparatus, of suspending wire, glass tubes, covers (of O and P), rings, &c., by means of which the straw pendulums are made to depend for insulation on F only.

R, the horizontal tubular arm, fixed upon k^2, with its stoppers and notches (for the reception of the knife-edges in the rings). The eye-pieces and their adjusting apparatus used in the Dome for reading the scales of the

* First described in 1828. *Vide* "Mechanical Perspective," p. 19.

† This cowl was (long since) suggested by the Astronomer Royal and is a decided improvement.

‡ These improvements on the old parapluie, &c. (which did not exclude every drop of water during a violent driving shower) occurred to me since the reading of this Report, and are adopted in a complete electrical apparatus now constructing for the Royal Madrid Observatory.

electrometers are here omitted as not being absolutely necessary for the objects contemplated; but they can be, at any time, easily added.

A sheet of tin-foil is placed under O and P, and in good conducting communication with c^1.

S is the Henley electrometer, as modified by Volta (and formerly described).

T, the discharger (or spark-measurer), remains as also formerly described.

t^1 is a rod and balls, adjustable to height, and attached to one of the balls K, in the manner in which k^2 is attached to the other ball K.

The distinguisher, used for ascertaining the *kind* of charge possessed by the conductor, may be either the small Leyden-jar, combined with a gold-leaf electroscope formerly described; or the electroscope at fig. 2, which retains its charge very long whilst under the glass bell, and may be used for the above purpose without being removed from it*.

External Apparatus for Insulation, &c.—The apparatus represented by fig. 4, divested of the conductor (D), formed part of an instrument formerly alluded to (Report for 1844), and which was called a pluvio-electrometer. In lieu of the conductor a large copper dish was fixed upon the glass pillar (F), mounted on the tripod which was placed on the leads of the Observatory, and the dish was connected by a wire with a separate insulating apparatus in the Dome, for the purpose of examining the electricity of rain. Deeming the employment of a dish objectionable, however, I made little use of the instrument for that purpose; but it has been found very convenient in the form here described as an external and portable apparatus, placed in situations where it would have been inconvenient and expensive to have erected a round-house observatory (as fig. 3). Some electrical observers would probably derive advantage from its use, in preference to the rod projecting from a window, as in Volta's, Cavallo's, my own former, and many other experiments; for it requires a very long rod thus used to get rid of the baneful effect of the house-top, chimneys, &c., particularly when the wind passes over the house from the side opposite to that from which the rod projects.

G (the table) is, in this case, supported by 3 triangular strong boards or frames, attached, by strong hinges, to its under side, and provided with edge-pieces or "feather-boards," for diminishing vibration, &c.; they can be folded inward, for the sake of portability, &c.

g^1 g^1 are 2 of 3 pieces of sail-cloth, which, by means of studs (or buttons) on the boards or legs, and of corresponding hooks upon g^1 g^1, can be laced (with small cords) upon the legs, so as to fill up any or all the spaces between them, and thus prevent the interference of wind with the lamp.

D, the conductor, and

F, the glass pillar, &c., are nearly similar to those of fig. 3, but stronger. The warming lamp is much more powerful than the lamp of fig. 3, in order that it may counteract the colder atmosphere to which this apparatus is usually exposed.

a^1, the cylinder, shown by dotted lines, and corresponding in some respects with a^1, fig. 3, is of copper, and protects F from rain, &c.

This apparatus may be placed on the roof of a house, and a wire, or (better) a rod, led from it, may communicate with an internal apparatus as the part

* It may be convenient to attach this (with its glass bell) to one end of a *long* arm or bracket revolvable horizontally upon a strong pivot at the other end.

H, &c. of fig. 3, or it may be placed in any high situation on the earth, at a distance from buildings, &c., and a long wire may be attached to a stronger and shorter rod taking the place of D. This wire may communicate with internal apparatus, and thus Beccaria's principal method of observing the electricity of serene weather, dew, &c. may be adopted and compared with others, and with the electricity of higher strata of the atmosphere.

Or (much better), several such insulators may be distributed over a considerable space and made to support several wires connected with each other and with the internal apparatus.

A large network of small wire thus insulated has long been a desideratum with me. The pillar F, &c. might be inclined for the sake of acquiring a better position for resisting the weight of such network.

For examining the electricity of rain in Cavallo's manner, a hoop of copper supporting a net work of wire, as shown by the dotted lines, might be advantageously substituted for the above-mentioned dish or the conductor D.

Three such insulators might be placed in an equilateral triangle, and 3 light cords, containing very fine wires, might be attached to an electrical kite, thus maintained at a nearly invariable height, as was done by lines not wired, in a rough experiment made here in 1847, with a view to temperature and hygrometric observations (vide Phil. Mag. for September 1847).

The *Photo-Electrograph* remains nearly as described in the Phil. Trans. Part I. for 1847. It will be improved by the addition of a little apparatus applicable to the registration of electrical frequency, and removed into the Dome.

Anemometer, &c.

The *Wind-Vane* remains as described in the Report for 1844, p. 129.

The *Balance Anemometer* of metal—an improvement upon that described in the Report for 1844, p. 129, and precisely similar in principle, but more sensitive—will be particularly described when further contemplated improvements have been effected. It is supported upon either a pillar attached to the northern part of the balustrade of the leads, or upon one at the southern part, according to the direction of the wind. It turns to the wind on hard steel centres, and vibrates vertically upon hard knife-edges and rings, in the manner of a delicate scale-beam.

Rain Gauges, &c.

The *Rain- and Vapour-Gauge* is in the state described at p. 129 of the same Report. Wear does not seem to affect its sensibility. On November 16, 1850, it was removed from the support of the old rain-gauge and placed upon a strong tripod, very near to its former locality, viz. the southern end of the leads, and at the same height as before.

The old *Rain-Gauge* is a relic of His Majesty George the Third's collection of Kew instruments. Its aperture is a square foot. A bottle, the neck of which nearly fits the conducting-pipe, is placed beneath it, and a glass cubic-inch measuring vessel is used (in Howard's manner) to ascertain the amounts of rain.

Thermometers, Hygrometers, &c.

The *Thermometer-stand* (Plate XIX.), not before clearly described, and nearly similar to that of Greenwich, is situated in front of the northern entrance on the stone platform. The mean distance of its face from the wall (or door)

is about 5 feet. The height of the base (a^1) from the grass below the steps is about 11 feet, and from the stone platform 3 feet 9 inches.

A is a wooden painted frame 2 feet 6 inches square.

a^1, a base-board attached to the lower part of A, &c.

a^2, the underside of a strong piece (represented by dotted lines) attached to the upper part of A, &c.

a^3, an interior portion of a penthouse composed of very thin boards attached to a^1 and a^2.

a^4, a similar exterior part of the roof, nailed to three narrow fillets, which are also attached to a^3, and maintain an interval of about an inch between a^3 and a^4; thus allowing a free circulation of air between them.

a^5, the remaining part of the roof.

a^6 and a^7, rails; the former adjustable for height above the latter.

B is a strong spar or post, firmly attached by wedges, &c. to the balustrade; in its upper end is fixed a cylindrical pin, which freely enters a socket in the central part of a^2, and allows A, with all its adjuncts, to be revolved on the axis of B.

The *Dry Standard Thermometer*, C, by Newman, has a brass Fahrenheit scale divided to 0·5 inch. It was found on September 21, 1850, to read 32° in pounded ice*.

A *Dry Thermometer*, D, by Ronchetti, has an ivory Fahrenheit scale divided to 0·2 inch. The tube and scale are enclosed in a hermetically sealed thin glass tube. The index corrections, when it was compared with C (on September 21, 1850), were at 32° − 0·1, at 54° + 0·2, at 73° + 0·5.

A *Wet-bulb Thermometer*, E, by Ronchetti, is exactly similar (in form, &c.) to D. The coating of its bulb is of taffetas, and the conducting threads are of floss silk. Its index corrections, when it was compared as above, were, at 32° − 0·5, at 54° − 0·2, at 73° 0·0

c^1 is a glass fountain which supplies the water. It is mounted on an adjustable support.

The *Mason's Hygrometer*, by Newman, was attached to the stand at about the place of E until September 22, 1850. Its index corrections, when it was compared with C, as above, were at 32° 0·0, at 54°−0·1, at 73°−0·5.

The *Rutherford Maximum and Minimum Thermometers*, FF, by Newman, have boxwood scales, the minimum divided to 0·067, the maximum to 0·047 inch. The index corrections (as above found) for the maximum were, at 32°−1°·5, at 54°−9°·2, at 73°−2°·0, and for the minimum at 32°−0·3, at 54°−0·4†.

* Since the above was written comparisons of this thermometer with standards, made here, gave the following results:—

Readings of Newman's.	Error of Newman's.
32°	0°·00
43·5	+0·21
53·6	+0·42
62·2	+0·52
71·7	+0·54
81·7	+0·55
86·6	+0·58

† It is evident that these instruments attached to the stand may be always protected from

A new *Daniel Hygrometer*, G, by Newman, has been used in various positions.

The index correction of its immersed thermometer (found as above) was −0·3.

The old *Daniel Hygrometer*, G, by Newman, which gave place to the above (on February 1, 1851), had a small void in the mercurial column of the immersed thermometer.

The index corrections of this instrument, found as above, were at 32°−0·5, at 54°−0·3.

The *Saussure Hygrometer*, H, of eight hours, made by Richer of Paris, in 1815, and described in the Journal de Physique, tom. xxxiv., p. 58, has a scale of 100 parts. Some experiments made in September 1850, seem to show that the range of the index had extended 5 divisions on the side of "humidity," and an equal quantity on the side of "dryness."

An old *Standard Thermometer* made by Adams, in about 1768 probably, for His Majesty George the Third's collection, is contained in a thick metallic case, open in front. It has a brass Fahrenheit scale divided to 0·059 inch. Its index corrections, when it was compared with C, as above, were at 32°−0·5, at 54°−0·5.

A *Regnault's Hygrometer and its Aspirator* in their original forms have been presented to us by Capt. Ludlow, R.E., together with several spare glass cisterns whose lower parts are formed of thin black glass, in addition to other cisterns compounded of silvered and glass tubes united by cement. These instruments have been described by M. Regnault*.

The comparisons of its two thermometers, No. 151 and No. 152, with the Newman's standard C, on September 23rd, 1850, gave the following results:—

Newman's.	No. 151.	No. 152.
32°	63°·1	90°·9
54·5	120·0	140·0
72·5	166·0	178·6

An improved Regnault's Hygrometer and Aspirator have been made, and may be thus described:—

A (fig. 1, Plate XX.) is the cistern, composed of a light and highly-polished silver tube. A little cylinder, of solid glass, occupies about an inch, measured from its bottom, and æther the principal part of the space above the glass.

direct influences of the sun's rays, wind, and rain taken separately, and sometimes collectively, by revolving A about B, but the difficult problem of always protecting them from all these influences simultaneously, of also avoiding the anomalous effects of radiation and humidity from neighbouring bodies, and of preserving a sufficiently free circulation of air, has, I fear, still to be solved.

* The distinguishing feature in the action of M. Regnault's admirable Hygrometer, as compared with that of the Daniel, is the deportation of ætherial vapour from the interior of a mass of æther (as well as from the surface) contained in a light metallic or glass cistern, by a current of air (bubbles) passed through the æther, and cooling the cistern down to, or beyond, the dew-point. The aspirator, a vessel containing water, and whose upper part communicates with the cistern of the hygrometer (only) by means of a flexible pipe and stopcock, is employed to create (and regulate with great precision) the current of air (and consequently the rate at which the cistern is cooled) by the flow of the water from its lower part.

a^1 is a brass cap soldered to A.

a^2 is part of a small vent (or cock) opening into A.

a^3, a tube (of the vent) with a small aperture at the pointed end, which when turned downward, permits fluid (above the opening of a^2 into A) to pass out, but when turned upwards that opening is entirely closed. By these means it is easily ascertained when æther enough has been poured into A.

a^4 is a stop-cock communicating with A and D, and serving as a support for A, &c.

B is the immersed thermometer, the tube of which passes (with cement) through a little pipe soldered to a disc (not shown) which rests upon a flange in a^1.

b^1, a ring (with milled edge) screwed upon a^1, and serving (with a leathern washer) to press the disc (carrying B, &c.) firmly down upon the flange in a^1.

C is a pipe for admitting air (and also for feeding A with æther) on occasion; it passes through the above-mentioned disc (with cement), and extends nearly to the solid glass cylinder in the bottom of A. Its upper end is funnel-shaped. When the instrument is not in use, this end is closed by a milled-headed stopper and leathern washer (to prevent the escape of ætherial vapour).

D is a brass column having a cylindrical bore throughout its length, excepting the upper plane of the cube; a^4 is screwed into the cube and communicates with the bore.

A glass shade may be placed over A, D, &c., for protection from rain, dust, &c. (on occasion).

E, figs. 2 and 3, is the aspirator.

e^1 is a pipe fitted into the bore of D, and entering

e^2, which is a square piece perforated horizontally and ground to fit exactly upon

e^3, which is a tube, closed by plugs, at its left end and its central part (in the manner shown in fig. 3). A perforation through the (always) upper side of e^3 and through e^2 admits a free passage of air, ætherial vapour, &c. from e^1 into e^3.

e^4 is a squared piece perforated horizontally, and ground to fit exactly upon e^3, but having liberty to revolve upon e^3 on occasion.

e^5, a pipe entering e^4, and *now* ascending from it. Another perforation through the (always) upper side of e^3 admits a free passage of air from e^3 to e^5 when e^5 is in the position shown.

e^6 is a rectangular vessel into which e^5 opens, very near to its *now* upper surface; and e^5 is soldered at the place where it passes through the *now* lower surface of e^6.

e^7, a pipe opening at a small distance from the now interior bottom of e^6, and from the now interior top of

e^8, which is a vessel exactly similar to e^6.

e^9 is a pipe opening into the now upper part of e^8, and entering

e^{10}, which is a squared piece perforated horizontally to fit upon e^3, but having liberty to revolve upon e^3 when necessary. A third perforation through e^3, at its always lower side, and through e^{10}, admits a free passage of air from e^8 to e^3.

It is evident that if e^6, in its present position, should contain water, and that if a current of air were permitted to flow through e^1, through the left-hand hollow part of e^3, and through e^5, the water would descend through e^7, and air, in e^8, would escape through e^9, and through the right-hand end of e^3, or (*vice versâ*) that the descent of water from e^6 to e^8 (through e^7)

would create a tendency to a vacuum in e^6, which would cause air to flow through e^1, &c. into e^6; and that when all the water had descended into e^8, air would cease to flow into e^6.

e^{11} is a pipe entering e^4, and opening into the now lower part of e^8, but having at present no communication with e^3 (for there is no opening in the lower side of e^3 at this point).

e^{12}, a pipe entering e^{10}, and opening into the now lower part of e^6, but at present having no communication with e^3 (for there is no upper opening in e^3 at this point).

It is therefore also evident, that if the vessel e^8 were made to take the exact position of e^6, by simply reversing the whole aspirator E, *i.e.* by turning it on the pieces e^4 and e^{10}, the pipes e^{11} and e^9 (which open into e^8) would occupy the positions now occupied by e^5 and e^{12}, and that consequently air would again flow through e^1, &c.

But e^1 communicates with D, D, with the cistern A (fig. 1), and A with C, therefore air would flow through C, would rise (in bubbles) through the æther in A, carrying with it a large quantity of æthereal vapour, and would pass through a^4, D, and e^1, &c. (fig. 3) into e^6, and so on.

F (fig. 2) is a strong table in two perpendicular legs of which notches are cut for the reception of the ends of e^3.

$f^1 f^1$ are plates, fitted to squares at their ends and screwed upon those legs, in order to prevent e^3 from rotation when e^6 and e^8 are made to exchange positions.

It is not necessary to enter upon further details here. The construction presents no difficulties (the kind of work required being principally that which is commonly executed by makers of stop-cocks, valves, &c); the parts of e^3 whereon e^4 and e^{10} revolve are slightly conical, and clamping nuts are employed.

The apparatus is very effective and convenient. With æther of second-rate quality the mercury has been made to descend from about 63° to about 13°. Even pyroligneous æther or good naphtha are efficient, but act injuriously upon the metal.

The lower part of A remains bright when the other part begins to be clouded with dew, thus affording the advantage of contrast in the discovery of the dew-point, but the line of demarcation is not always perfect at first. Further improvements relative to this object are contemplated. The freezing-point of B (as determined on April 3, 1851) is at 32°·2.

An Hygrometric Sliding Rule, invented by Mr. Welsh (of this Establishment), has been added to our stock of working instruments. The following is his abstract from his description of this ingenious contrivance.

"The hygrometrical sliding-rule has been devised for the purpose of facilitating the calculation of the results of observations with the moist-bulb hygrometer. The instrument is founded on Dr. Apjohn's formula, Dalton's values of the elasticity of vapour being adopted. It has been so arranged as to give by inspection the values of the following expressions:—1st. The elastic force of the aqueous vapour. 2nd. The temperature of the dew-point. 3rd. The relative humidity of the air or the ratio to complete saturation; and 4th. The weight of water contained in a cubic foot of air. The scales were divided on metal at Kew by the aid of Perreaux's dividing-engine, and afterwards copied upon wood by the optician."

A *Standard Thermometer* by M. Regnault, No. 231, has been received

from Col. Sabine. The length of its arbitrary scale (beautifully etched upon the tube) is 17 inches. The range is from −5 to +235, and the number of divisions is 650.

The boiling-point (as determined on April 3, 1851) is at the 591st division, and the freezing-point at the 100dth.

A *Standard Thermometer* by Ronchetti, has been also received from Col. Sabine.

The freezing-point (as determined on April 3, 1851) is at the 31°·4 division.

A Machine for dividing right lines in equal parts, on Ramsden's principle, but very ingeniously modified by M. Perreaux, with appendages for fixing calibring and graduating thermometer-tubes, has been, very seasonably, imported and added to our collection under the auspices of Mr. Gassiot. The important application of M. Perreaux's machine to the above-mentioned and other purposes was effected with the aid and advice of M. Regnault; and the instrument, together with the modes of using it, have been clearly described and illustrated by M. Soulnier in a Report of July 8, 1846, inserted in the 'Bulletin des Sciences*.'

Apparatus for testing the graduation of Thermometers, and some for comparing them and for determining the freezing- and boiling-points, formed other portions of Mr. Gassiot's valuable importation.

Barometers.

The Mountain Barometer by Newman (*vide* Report for 1844), formerly suspended freely, and not quite vertically, at the N.E. window of the Quadrant Room, is now fixed at the central window of that room by means of an adjustable screw above and an adjustable bracket below for ensuring perpendicularity.

"The frame-work of the barometer is of wood, a brass scale 13 inches long being affixed. The diameter of the tube is 0·17 inch. There is no adjustment for the different capacity of the tube and cistern. The neutral point is 29·764 inches. The capacity $\frac{1}{55}$ and the capillary action +0·043. The brass scale does not extend to the cistern. The height of the cistern above mean water is ."

A *Standard Barometer* by Newman has been sent by Col. Sabine from Woolwich, and is fixed near to the eastern wall of the Transit Room. It is mounted in a metallic frame, and is the same in principle as that made for the Royal Society. It is furnished with the improved iron cistern (for facilitating transport). It has not been compared with the Royal Society standard. "The diameter of the tube (bore) is 0·55 inch. The height of its cistern above mean water is ." A thermometer whose bulb is plunged in a short tube containing mercury has been fixed near to the column on the back-board, for temperature corrections of the column.

The Photo-Barometrograph, placed near the central window of the Quadrant Room, is the result of several improvements upon experimental apparatus used here in August 1845†. It has been alluded to in former Reports, &c.,

* A trivial addition of clamps has been made here for applying it to the graduation of magnetograph scales, &c.

† And described in the Phil. Trans., Part I. for 1847.

but has not been particularly described, because time and opportunity have scarcely permitted an examination of its qualifications as to self-correction for temperature, which was always considered a principal desideratum. The experience obtained this year, of its efficiency to a very great (if not complete) extent in this respect, may perhaps be deemed a sufficient apology for the following details.

Fig. 1, Plate XXI. represents the instrument closed and at work by daylight. Fig. 2 represents it with some of the cases withdrawn. Figs. 3, 4 and 5 are projections (drawn to one-fourth of the real size) of the barometer and compensating apparatus only. All the figures of Plate XXII. are sections, &c. drawn to one-eighth of the real size.

AA^1 A^2, Plate XXII., are sections of the mahogany cases which constitute the camera. A^1 has apertures, or diaphragms, about 2 inches broad, through the right and left sides.

a^1 is frame-work (composed of a pair of brackets, &c.) firmly secured in its place by long bolts and nuts, &c. at the image end of the camera.

B is the barometer compensated for temperature, in the manner to be described presently.

b^1, the surface of mercury in its tube.

C is the first condensing lens, the frame-work and the shutter apparatus; the whole supported by brackets, and forming the object-end of the camera.

c^1 c^1 are grooved pieces; between which slides, laterally and freely,

c^2, which is a plate having a rectangular aperture about 3 inches high and 2 inches broad. It can be made to admit light to the camera or exclude it at pleasure, by being slid laterally.

c^3 is a second condensing lens.

O is a diaphragm-plate. The aperture is about $\frac{1}{20}$th of an inch broad and about 3 inches high.

D, an Argand lamp (of new construction, to be hereafter described).

E is the usual mouth-piece, consisting of the two (usual) angular pieces, and of two thin plates attached to their right sides, which form the lips.

e^1, the vertical interval between the lips; it is about 4 inches high and about $\frac{1}{10}$th of an inch broad.

F is the slider-case attached to the pair of brackets at a^1.

f^1, its lower side, is as nearly plane as possible. (It *should* be of brass or marble.)

f^5, a spring roller, shown only in fig. 2, Plate XXI., attached to the interior side of the door of F.

f^6, a narrow aperture through the central part of the door of F.

G is the lens-tube, containing two groups of achromatic lenses by Voigtlander (of Vienna). The magnifying power is about $=2$ times.

g^1, apparatus, of sliding-plate, &c., for the support and adjustment to focus of G.

H is the sliding-frame.

h^4, its door, with a narrow aperture near its right end.

h^5, &c., three turnbuckles (sunk in h^4).

h^1, &c., three springs attached to the interior side of h^4, and acting upon the back of the Daguerreotype plate (or upon a pair of glass plates, pressing between them a piece of Talbotype paper) contained in H.

y (fig. 4) represents the front of that plate or paper contained in H.

h^2 h^2 are studs containing rollers. They are attached to a thin narrow plate, and constitute, with it, a kind of carriage which travels on f^1.

h^3 h^3, small screws for retaining cords.

h^6, a brass plate, capable of sliding *freely* in a groove in H and over y. Its left end is cut (in the manner shown) to form a hook, which may be made o fit (or rest upon) alittle peg projecting from the back of F.

h^7, a plate of ground glass fixed in H opposite to the narrow aperture in h^4, with its ground surface exactly in the upper plane of y. Upon this plate a scale divided to $\frac{1}{50}$th of an inch is etched.

When both h^6 and H are placed in F, h^6, before the commencement of the registration, covers y entirely, and the position of h^6 is such, that its right end stands at about $\frac{1}{20}$th of an inch to the left of e^1. The image of b^1 is visible on the scale etched on h^7 through the aperture of h^4.

I is the pulley on the barrel arbor of the time-piece.

i^1, a small gut cord passing through F and attached to I and to one of the studs h^2.

i^2, a cord passing over

i^3, a pulley, and suspending a weight (not shown).

i^4, a cord attached to I, and sustaining

i^5, which is a counteracting weight rather heavier than the weight (not shown) suspended by i^2.

i^6, a clamping milled-headed nut, screwed on the barrel arbor of I. When it is relaxed I can revolve freely on the arbor.

K, the case of the time-piece.

k^1, a pointed index fixed on K (and serving the purpose of a hand).

k^2, a milled-headed nut attached to an arbor passing through the clock-plates, and connected with a lever and fork, &c. behind, which can be made to stop or release the pendulum at any given moment (by turning k^2)*.

k^3, the support of K, and adjustable for height.

P P, bearers supporting A, A^1, A^2, B, &c. (*vide* fig. 2).

Q, a cross bearer supporting F, &c. (*vide* fig. 3).

All these bearers are of well-seasoned and straight-grained deal, and bolted together accurately.

R is a case, supported by rabbeted pieces under P P, and capable of being slid to and fro. It protects the lower part of B from dust, &c.

The manipulation and action of that part of the instrument, &c. which has now been described is (shortly) as follows:—

1st. Y having been *duly* polished (in the board, fig. 3, Plate XVIII., Report for 1850), is placed in H, and coated by placing H in the coating boxes (fig. 5. Plate XVIII. of same Report).—2nd. h^6 is slid over Y (still in the coating box).—3rd. H, &c. is placed on the carriage h^3 h^3 (fig. 3, Plate XXII. of this Report), resting at the left end of f^1; and, at the same time, the hook of h^6 is fitted on a pin projecting from the back of F.—4th. The door of F is closed; thereby causing the spring f^5 to press upon h^4, and to cause h^6 to press upon the left lip at e^1 of the mouth-piece E (*vide* fig. 2, Plate XXI. &c.).—5th. The *image of* b^1 on the ground-glass scale h^7 may then be observed through the narrow apertures in the doors of F and H, in order to verify focus, &c.—6th. The time-piece in K is started, at the proper moment, by means of k^2. The revolution of I now causes H, &c. to move, at the rate of half an inch per hour, to the right, carrying Y with it, but leaving h^6 at rest. Successive portions of V are therefore exposed to the action of light passing from D, or from a window, through C, through c^3, through the tube and vacant part of B above b^1, through G and through e^1; and if b^1 varies its height, during the motion of H, &c., unequal portions of Y are acted upon by the light.—

* *Vide* fig. 7, Plate I., Report for 1850.

7th. At the end of a day (or any given period) K is stopped, the nut i^6 is relaxed, and H is drawn back (by pulling i^3) to its original place in F.—8th. H, together with h^6, are carried into a dark room (or closet), where Y is withdrawn from H and placed in the (warmed) mercury-box.—9th. When taken out of the mercury-box, Y exhibits a figure as (e.g.) $y^1\,y^2$, fig. 4, which indicates that portion of Y which had been exposed to light (in F), the line y^1 being the curve of barometric variation, and the line y^2 its abscissa.—10th. After the usual washing in the hyposulphite of soda-solution, Y is fitted to the ordinate and tracing-boards (fig. 2, Plate XXI., Report for 1849), and the tabulation and tracing processes are proceeded with.

The compensating apparatus will be readily understood by reference to figs. 3, 4 and 5, Plate XXI., &c.

b^2 is the cistern; the glass cover of which is accurately fitted on it and clamped, by means of two triangular plates (*vide* fig. 4) and three long screws. This cover has a neck through which the upper part of B has been passed from below, and the lower part of B being slightly conical (the base of the cone being below), is ground into the neck, so as to suspend the cistern b^2 securely.

b^3, a ring through which the tube was slid before a globular enlargement which prevents it from sliding back again was made.

b^4, a piece attached to b^3 by two screws, and provided with a little eye, through which a short untwisted skein of silk passes and sustains the whole barometer.

b^5, a ring partially surrounding the tube (*vide* fig. 5).

b^6, &c., three adjusting screws for preventing accidental oscillations of the barometer, but not actually touching the tube.

$b^7\,b^7$ (fig. 3) are two very old and straight-grained pieces of deal.

$b^8\,b^8$, brass pillars connecting $b^7\,b^7$ by means of screws and washers.

$b^9\,b^9$, brass plates screwed upon $b^7\,b^7$.

b^{11} and b^{12}, rods of hard zinc, upon the ends of which are soldered brass caps.

The upper cap of b^{11} is attached to b^9 at (by hypothesis) an invariable point, and its lower cap to a joint at one end of

b^{13}, which is a lever whose fulcrum is at about the distance of one-third its length from this joint. The lower cap of b^{12} is attached to a joint at the other end (of b^{13}), distant two-thirds of its length from the fulcrum. The upper cap of b^{12} is attached to a joint in

b^{14}, which is a piece capable of being slid in a mortice by the action of a milled-headed screw in

b^{15}, which is a lever whose fulcrum is at the distance of about one-third its length from the joint in b^{14}. The left end of b^{15} is provided with a piece curved to radius of its distance from the fulcrum, which distance is equal to two-thirds the length of b^{15}, and this arc receives the silken skein which sustains B. The fulcrum of b^{15} is a hard steel knife-edge working in a hard steel ring.

b^{16} is an index, of thin brass, attached to b^{15}, and pointing a scale engraved on b^9.

$b^{17}\,b^{17}$ are screws which screw through pieces attached to $b^7\,b^7$, and bear upon plates with sockets adjustable on P P. They are used for small adjustments for height, perpendicularity, &c. of the whole frame (composed of b^7, b^8, &c.).

b^{18} (*vide* fig. 2), a piece projecting from the legs to prevent oscillations of the said frame, but not fastened to it.

It is evident that, by this arrangement, B would descend through a space equal to *about* six times the amount of the expansion of b^{11} or b^{12}, occasioned by any given increment of temperature (a quantity equal to the difference of expansion between zinc and mercury), provided that no expansion should occur in b^7 b^7; but b^{14} is made adjustable to a greater or less distance from the fulcrum of b^{15}, for the purpose, not only of compensating the expansions of b^7 b^7, but for endeavouring to correct other obvious little sources of error.

Magnetographs.

The *Declination Magnetograph*, placed between the piers of the (transferred) transit instrument, and described in the Phil. Trans., Part I. 1847, has undergone the following improvements:—

The index (b^1) which was formerly used in producing the curve on paper, has given place to a moveable shield, with its slit similar to b^1 of fig. 1, Plate V., Report for 1849.

A diaphragm plate, similar to O, has been added, with provision for adjusting it, on the marble slab, in the direction of the length (of the slab).

A fixed shield, like o^1, has been attached to O, with the intervention of a pair of sliders, moveable vertically and horizontally, by means of micrometer screws, which allow it to be returned to its place if derangement in either of these directions should occur; and the adjustments of O, on the slab, determine its proper horizontal distance from b^1.

A socket has been fixed upon the lamp-support, which guides the lamp into a constant position when exchanged at about sunrise for a plane mirror, for which a similar kind of guide has been provided.

This mirror is at present necessary for reflecting daylight into the camera from a window (the locality not permitting direct daylight to enter it), and consequently it is also necessary to keep the mouth at E much more opened than the mouths of the other two magnetographs, in order to compensate the loss of light by a longer exposure of the photographic surface in the slider (H) to its influence; this has (evidently) a bad effect upon the magnetic curve, particularly on occasions of considerable and sudden magnetic disturbances.

The microscope (f^6) has been made capable of being slid laterally, in order that the image on the ground-glass (at e^1) may be viewed more directly; for the principal part of what was before mistaken for other kind of aberration arose in fact from the circumstance of viewing the image obliquely through the microscope.

The sliding-frame H has been provided with a scale, etched upon a piece of ground-glass, to serve for verifying scale-coefficients, &c. The scale is divided to fiftieths of an inch, corresponding to the divisions of the T square used with the scale-board (fig. 2, Plate IV., Report for 1849). Also an additional pair of rollers like b^2, fig. 2, has been attached to the left side of H; and an additional ring has been fixed on the bottom, in order that the frame may be employed in an inverted position in the slide-case (F), and that thus the trouble of either preparing two plates per diem, or the necessity and risk of withdrawing from and replacing the one plate in H (at 12 P.M.) might be avoided*.

These and some other little ameliorations in this instrument were made

* It was not originally intended that the plate should be inverted (*vide* fig. 2, Plate XXI.) for the purpose of procuring the two new lines and the two curves on it. The effect of the new arrangement has been, in a few instances of magnetic disturbance, to contract the field on the plate for the range of the image of the slit so much as to exclude a part of the curve.

with a view of adapting it to the course of experimental trials, as well as its wooden supports and other wooden appliances, and the use of a mirror (as above) would permit. It was well known to Col. Sabine and to other gentlemen of the Kew Committee, &c., before those trials began, that although a long series of good curves on paper had been produced in 1846, and some exhibited at the Royal Society in 1847, yet no expectation of accuracy approaching to that obtained by the other two magnetographs, as regards distinctness of the curves, &c., was ever entertained. It may be also remarked that its locality is a passage room, and is used for several other purposes.

The arc value of 1 inch or 50 divisions of the ordinate scale for this instrument is, when corrected by the torsion coefficient, 28·71 (*vide* p. 362, *post.*).

The time of transit of a given point of the photographic surface over the mouth at (c^1) is about $5\frac{1}{2}$ minutes (as formerly ascertained).

The *Horizontal-Force Magnetograph,* placed on the stone brackets solidly attached to the great quadrant wall (and described in the Report for 1849, &c.), has undergone the following alterations:—

A damper, 3 inches broad, $\frac{1}{2}$ inch thick, and having its interior horizontal surfaces about 1 inch apart, has been substituted for the former damper (b^4), about $\frac{3}{4}$ inch broad, with its interior surfaces about $1\frac{1}{2}$ inch apart. This variation was kindly suggested by Dr. Faraday on a visit to Kew, and has proved (as he anticipated) a very profitable one. The magnet, which always performed well, has been rendered remarkably steady by this improvement.

A new thermometer (by Cary), the tube of which passes through a stopper in the top of the case, has been affixed.

Screens have been placed between the lamp and the cases for protection of the magnet against the heat of the flame.

The sliding-frame (H) has been treated in exactly the same manner as that of the declination magnetograph.

The arc value of 1 inch of the ordinate scale is 109·4.

The diameter of the pulley (at s^6) is 0·464 in.

The distance of the ends of the wire (at S) is 0·413 in., and the angle of torsion 64°·45.

The temperature corrections on December 14 were, at 55°·3=0·000312, and at 76°·2=0·000344.

The time of passage of a point of the photographic surface over the mouth e^1 is about $1\frac{1}{4}$ minute (*vide* p. 360, *post.*).

A new *Vertical-force Magnetograph* has been constructed and fixed upon the three corbels (already mentioned) on the quadrant wall. Its magnet is nearly perpendicular to the plane of the astronomical meridian, the locality not, at present, permitting a more favourable disposition.

This instrument is, in most respects, similar to the vertical-force magnetograph which was sent to the Toronto Observatory, and described in the Report for 1850.

The following little variations and additions have been made:—

The four brass pillars (Q, fig. 1, Plate II. of that Report) have been temporarily removed, the intermediate corbel sustaining the magnet, &c. contained in the case V*.

* The slab X rests upon the two corbels which are used instead of the piers P^S and P^N, fig. 1, Plates I. & IV., Report for 1849; and the slab R, fig. 1, Plates I. & II., Report for 1850, was at first supported by the strong bolts, nuts, &c. of the pillars Q, only very near to

An improved mode of attaching the diaphragm plate O, figs. 1 & 2, to the slab X has been adopted, whereby the horizontal distance between the two shields b^1 and o^1 is now very easily adjusted.

A screen has been (occasionally) interposed between the lamp and the camera.

A new long-tubed thermometer (by Cary) has been affixed to the magnet case.

The sliding-frame H has been treated in the same manner as that of the declination magnetograph (*vide* p. 350, *antè*).

The temperature corrections of this magnet were, on December 14, 1850, at 50°·4=0·000283 and at 71°·5=0·000319.

The time of vibration (with its shield arm b^3 and all other appendages) in a horizontal plane was,—March 31, at a temperature of 52°, =17·9 seconds, and in a vertical plane at 53°, =20 seconds; but its time of vertical vibration has been found several times altered since that day.

The arc value of 1 inch or 50 divisions of the ordinate scale is 76·23.

The transit of a given point of the photographic surface over the mouth (e^1) is $1\frac{1}{2}$ minute (*vide* p. 361, *post.*).

Apparatus used in ascertaining arc values of the ordinates of the curves and errors from distortion, &c. has been made. It is of a very simple kind, but may be said to consist of four parts.

The first is a plate of transparent glass, about $3\frac{1}{2}$ inches long and $\frac{3}{4}$ths of an inch broad, supported by a pair of pillars, &c., and having a scale etched upon it divided to $\frac{1}{50}$th of an inch.

The second is a plate of glass, ground to semi-transparency of similar dimensions, fitted into a frame and similarly divided.

In making use of these two to ascertain the magnifying power of the lenses, the transparent scale is placed with its undivided face in contact with the fixed shield (o^1) of all the plates of magnetographs, its scale occupying the locus of the slit itself in the moveable shield (b^1) (if the magnet, &c. were in position), and the semi-transparent plate is placed, with its undivided face, in contact with the mouth-piece (E), its scale occupying the locus of the *Image* of the slit in the moveable shield (the thickness of both plates being properly adapted to the purpose).

The lenses (of G) are then adjusted to bring the image of the first-mentioned scale into focus as nearly as possible upon the second scale, so that the *image* of the first scale and the *second scale itself* can be conjointly and scrupulously examined by the microscope (f^6) and the corresponding readings noted.

The third part is merely a long scale, &c. which is employed to measure the exact distance between the common axis of motion (of the magnet, the shield-arm, &c.) and the moveable shield.

The fourth is (applicable to vertical force instruments only) for measuring the radius from the knife-edge (at b^6) to that part of the slit in the moveable shield which produces a corresponding spot of light at the mouth (e^1) upon the second glass plate.

one of the above-mentioned two corbels. The new short corbel is a substitute for the short pier P^s, fig. 1, Plate I., Report for 1850, but this substitution has been here found unnecessary (*vide* p. 361, *post.*). The original plan of supporting this kind of instrument, *i. e.* the method described in the Report for 1850, where the short pier and the pillars are used conjointly, and where no pier sustains the extremity of the slab X, is, however, far preferable perhaps.

It consists of a pair of sliding tubes, the outer fixed, exactly at right-angles, to a little base of copper, and a shield with a slit, similar to the ordinary moveable shield (o^1,), fitted to the upper end of the inner tube.

In using this the copper base is made to rest upon the agate planes (at s^6) in lieu of the ordinary knife-edge of the magnet; the inner sliding tube is then slid up or down until the slit in the shield comes to about its proper height in the plane of the ordinary moveable shield. Its edge is now marked exactly at that point which produces a corresponding point in its image at the mouth (e^1), and the instrument being removed from the agate planes, the distance from the lower surface of the copper base to the point marked at the edge of the slit is easily measured, and is evidently the radius required*.

The apparatus which has now been described affords *us* a much more convenient means of obtaining the required values than a mirror or a collimator (attached to the stirrup, &c.), since the shield-arm (b^3) of the declination and horizontal-force magnetographs must have the same angular motion as the magnet, and it can (as formerly shown) be properly adjusted in azimuth about the common axis of motion: also there is a provision at the base of the vertical-force magnet-support which permits a proper horizontal adjustment for the position of the moveable shield of that instrument.

The first parts may be said to be modifications of contrivances which have been formerly used for purposes of the same kind as those to which they are applicable. (They are not quite so accurate, but a little more convenient†.)

The *Scale Board, Lens,* &c. used in tabulating all the self-registered curves remain as described at p. 85, Report for 1849.

A *Drawing Board with Clamps* is used for securing the gelatine paper and Daguerreotype plate firmly in their places for the tracing process.

A *Sliding-rule*, invented by Mr. Welsh, has been constructed on the same principles as that described at p. 345, "for converting the observed changes of the horizontal and vertical components of magnetic force into variation of dip and total force."

A few specimens of the earlier and latter Daguerreotype curves on their silvered plates have been preserved; also some gelatine tracings, some impressions printed from the gelatine tracings on bank-note paper, and some

* Great inconvenience and (probably) damage to the knife-edge would ensue from any attempt to acquire this measurement by means of the shield-arm (b^3), itself in position.

† The magnifying power of the lenses of the Declination Magnetograph was, in 1846, ascertained by marking with angular notches, a space of about $\frac{4}{5}$ths of an inch on the edge of a thin lamina of brass, placed in the plane of the moveable index, and by comparing the length of the image projected upon ground glass at the place of the mouth (E) of the said space with the space itself (on the slip of brass).

The above-mentioned transparent glass scale is a modification of a metallic screen provided with a series of slits, formerly used (and described at p. 181, Report for 1850) in adjustments for focus, and a plate is preserved exhibiting good and *equally* distinct impressions of the images of those slits.

The distortion occasioned by the use of a plane in lieu of a curved surface to receive the image, was, from the first, a subject of great solicitude. It was no easy task to obtain a tolerably "flat field" from so large a lens-aperture as I am obliged to employ upon an object much removed sometimes from the axis of the lenses and at a short distance from them, whilst the lenses were required to *magnify* several times in the conjugate focus.

In November 1849, Mr. Fred. Ayrton promised to procure for me from Paris some very finely divided scales, for the mouth-piece, on semitransparent horn, "for reading the arcs of vibration described by the magnet in its diurnal variations."

lithographic impressions printed, by first procuring in the copper-plate press an impression from the gelatine tracing itself, on the lithographer's "Transfer Paper," and by then printing from that impression transferred to the stone (as usual)*.

The *Apparatus of Polishing-boards, Coating and Mercurializing Boxes*, &c., remains nearly as described at p. 184, Report for 1850.

Four *small* polishing boards of this kind have been made, and seem to be improvements upon the frames employed by Daguerreotypists usually.

Mr. Dent's Chronometer, a Sextant, and an Artificial Horizon, have been used for keeping Greenwich mean time. The two latter instruments were sent by Colonel Sabine from Woolwich.

The Apparatus not (or very little) used

in this year, and belonging to the Association, or on loan to it, is enumerated in our MS. catalogue with all the above.

Books

presented to the Association by foreign Societies and by individual Donors in this year have been added to our little library, which now comprises about 150 volumes, exclusive of pamphlets and of the MS. Catalogue of Stars, &c.; the remaining number of complete sets of the Reports of the Association (to July 31, 1850 inclusive) at Kew is 24.

Some of the Royal Society's Instruments

sent here very recently for careful preservation will be forthwith catalogued.

II. OBSERVATIONS.

The observations at Kew in this year have chiefly related to investigations on the interesting subject of Frequency of atmospheric electricity, and a prominent object of the inquiry has been the attainment of data for the addition of proper apparatus to a Photo-electrograph of the kind formerly described†, whereby the study of this subject may be facilitated by means which appear to me peculiarly well calculated for the purpose.

The form of our Electro-meteorological Journal remains as described in my Report for 1844, with the exceptions observable in the annexed specimen and the following revised account.

In column A is stated the time of each observation by the Dent's chronometer, which "was kept always very near to Greenwich mean time by occasional sextant observations of the sun and by casual comparisons, by means of a pocket watch, with standard clocks in London. The epochs noticed in this column are,—1st, the time of the barometer observation, which was about the middle time of the ordinary meteorological observations. The temperature of the air and the hygrometer were observed before the barometer, and the wind, weather, &c. immediately thereafter; 2nd. the time of observing the electrical tension of the air and of the commencement of the frequency observation; and 3rd, the time when the electrometer was considered to have re-acquired its full tension after discharge."

* The tabulations and gelatine tracings produced during "the course of experimental trials," will, at its termination, belong, I presume, to the Royal Society (by agreement).

† *Vide* Phil. Trans. Pt. I. for 1847.

In column B the letter P indicates a positive and N a negative charge of the conductor, &c., as ascertained by the use of the Distinguisher.

In C and D the electrical observations of *tension* are noted as observed by means of the Volta- and Henley-electrometers. The letter V^1 refers to Volta's standard electrometer (whose scale is divided in half-Paris lines as stated), and V^2 to his second, whose scale divisions are each equal to 5 of the V^1 (as also stated). The value of tension, as observed by means of V^2, is set down in terms of V^1; the letter H refers to the Henley, one degree of whose scale, in the lower readings, is equal to about 100 divisions of Volta. (It has seldom been used for the frequency observations.)

The columns E, F, G, H have not been used.

In I are contained from 3 to 7 daily results, carefully obtained between September 10, 1850, and March 29, 1851, by methods somewhat differing from those which were adopted under instructions to the observer last year.

" Slips of paper, about 18 inches long, were affixed to the observer's clock. The brass time-scale, which is divided in accordance with the rate at which the index travels over the paper, was applied to the slips, and spaces corresponding to every 60 seconds marked off on the paper. At commencing a 'Frequency observation,' the tension was noted, the index was set to the zero division on the paper, and the clock started; the electrometer being at the same instant discharged. As the index came successively over each mark, the tension was observed by the electrometer and the scale reading recorded against the mark on the paper. These observations were continued (for the most part) until, from the progression of the readings, the conductor seemed to have acquired the full tension corresponding to the electrical state of the air at the period. The inverse measure of frequency adopted is the number of minutes between the time when the electrometer is discharged, and the time when the readings of the electrometer have again attained to one-half of their full amount. As the observations were in general continued until the tension shown by the electrometer had reached its full amount, we have thus a means of approximately allowing for the change in the electrical tension of the air during the progress of the experiment. The numbers given in the column 'Frequency,' are therefore, when the change of tension has not been great, got in this way, viz. half the mean between the tension shown before discharging the conductor, and that after the scale readings have again become constant, is taken; and the interval of time after discharge corresponding to this reading is taken as the 'Frequency.' "

In column K are contained the *original* readings of the mountain barometer until January 9, 1851, and of the standard barometer after that time.

In L the readings are those of the annexed thermometers, whose bulbs are immersed in the mercury of the cisterns.

In M the corrections of the mountain barometer embrace temperature corrections as applied to glass scales, given in the Report of the Committee of Physics of the Royal Society, which corrections were necessary, because the brass scale does not extend to the cistern. " All the observations of this instrument have been corrected for temperature, capacity and capillarity."

" The observations" of the standard " are all corrected for temperature by Schumacher's tables. No corrections have been applied for capillarity."

It was found by fifty comparisons, made with due precautions, &c., that " the mountain barometer read 0·02 inch higher than the standard. All the observations previous to January 9, 1851, will therefore require a correction of −0·02 to make them comparable with those after that date."

In N the readings are those of the Rutherford minimum and maximum

thermometers attached to the stand. "The index corrections have been applied. The minimum temperature was generally read at 10^h A.M. and the maximum at sunset."

In O are contained the corrected readings of the dry standard thermometer by Newman, until September 22 (23^h), and of Ronchetti's dry after that date; both affixed to the stand.

In P are contained the corrected readings of the small wet-bulb thermometer by Newman, which belonged to the Mason's hygrometer, until September 22 (23^h), and of Ronchetti's wet-bulb after that date.

In Q the differences between the readings of the dry and wet thermometers are stated.

In R is contained the observed dew-point by the *old* Daniel hygrometer until February 1, 1851. The little break in the mercurial column of the immersed thermometer of this instrument occasioned probably "no appreciable error in the observations, as a strict watch was kept on the constancy of the break." After February 1 the dew-point was observed by the new instrument. "The observations of dew-point, as entered in the Journal, have *not* been corrected for index error."

S has been scarcely used.

In T are contained some occasional readings of the Saussure 8-haired hygrometer, *not* corrected for the error of its scale.

In U and V are contained the results of observations of the rain- and vapour-gauge. The mode of using it was as formerly. "The reading was noted and the index set to zero at sunset. When the reading showed that the evaporation had been greater than the precipitation, the result was noted in column U; and when the reverse was the case, the entry was made in column V."

In W is contained the amount in cubic inch measure of precipitation between sunset and sunset, as ascertained by means of the old Rain-gauge and measure.

In X the direction of the wind is noted, as shown by the Vane on the Dome.

In Y the static pressure of wind is noted from observations of the Balance (standard) anemometer, used as formerly*.

In the space (*i. e.* a page) headed GENERAL REMARKS, &c., the figures adjoining the margin denote the estimated "Extent of cloudy sky, a clear sky being considered 0, and a complete covering of clouds 10."

"The general remarks and occasional observations include the kinds of clouds prevalent, general remarks on the weather and meteorological phænomena, and notes on the electrical observations."

They comprise, in addition, notices when the Lamp, in the Volta's lantern, at the head of the conductor was known to be not burning, or burning low.

Both that lamp and the lamp which warms the glass support of the conductor, &c., were constantly burning, with the above-mentioned rare exceptions. They were trimmed three or four times per diem.

A few other matters relative to the management, &c. of the apparatus, &c. are stated in this space.

Olive-oil was burnt in the lamps.

The average number of either compound† or single daily electrical obser-

* The Barometers, Thermometers, Hygrometers, &c., have been alluded to at pp. 341, 342 and 343, *antè*.

† A compound observation is understood to comprehend the notes of tension recorded on

Electro-Meteorological Observations, at the Observatory, Kew, in the Year 1850.

TIME.	ELECTRICITY.								BAROMETRIC PRESSURE.			TEMPERATURE.		HUMIDITY.								WIND.		
Day and Hour. Chronometer uncorrected.	Kind.	Periodical Observations.		Morning Min. and Maximum.		Afternoon Min. and Maximum.		Frequency.	Barometer uncorrected.	Attached Thermometer.	Barometer corrected.	Maximum and Min. Thermom.	Dry Thermometer.	Wet Thermometer.	Wet Thermom. below Dry.	Dew-Point.	Dew-Point below Dry.	Saussure's Hygrometer.	Vapour and Rain Gauge. Evap.	Vapour and Rain Gauge. Rain.	Rain Gauge.	Direction.	Pressure by Balance Anem.	GENERAL REMARKS AND OCCASIONAL OBSERVATIONS.
d h m		div.		div.		div.		min.	in.	div.	in.	div.	div.	div.	div.	div.	div.	div.	in.	in.	in.		grs.	
Nov. 13. 19 5	...	......	...	......	...	......	...	......	30·152	47·8	30·161	......	32·5	31·4	1·1	......	......	......	......	......	......	N.W.	800	2. Cirrostrati on horizon.
„ 19 10	P.	80	V_2.																					
„ 19 42	P.	83	V_2.	......	...	......	...	14·																
„ 20 0	...	......	...	......	...	......	...	......	30·181	47·4	30·192	......	32·1	31·1	1·0	30·0	......	88	......	......	......	N.N.W.	1000	1. Cirrostrati on horizon. Fine clear morning.
„ 20 7	P.	78	V_2.																					
„ 20 21	P.	80	V_2.	......	...	......	...	4·7																
„ 21 57	...	......	...	......	...	......	...	......	30·222	49·6	30·228	32·3	37·4	35·5	1·9	32·6	......	85	......	......	......	N.	400	0. Clear except a streak or two on horizon.—22h 4m. Dry 39·85. Wet 36·87. Daniel 32·3. Saussure 79.
„ 22 0	P.	84	V_2.																					
„ 22 19	P.	82	V_2.	......	...	......	...	9·5																
Nov. 14. 0 55	...	......	...	......	...	......	...	......	30·242	51·0	30·245	......	44·	38·9	5·1	31·8	......	67	......	......	......	N.	3000	1. Cumuli.
„ 0 59	P.	76	V_2.																					
„ 1 23	P.	60	V_2.	......	...	......	...	13·																
„ 3 55	...	......	...	......	...	......	...	......	30·266	51·0	30·269	......	41·9	38·4	3·5	33·6	......	75	......	......	......	N. b W.	600	1. Cirrostrati on horizon.
„ 3 59	P.	101	V_2.																					
„ 4 11	P.	85	V_2.	......	...	......	...	1·5																
„ 4 14	P.	84	V_2.																					
„ 4 27	P.	78	V_2.	......	...	......	...	2·																
„ 6 56	...	......	...	......	...	......	...	......	30·304	48·7	30·313	......	35·3	33·6	1·7	......	......	......	......	......	......	N.N.W.	50	0. Clear.
„ 7 2	P.	81	V_2.																					
„ 7 7	P.	74	V_2.	......	...	......	...	0·8																
„ 10 10	...	......	...	......	...	......	...	......	30·338	47·5	30·351	......	30·2	30·	0·2	......	......	......	......	......	......	S.W.	200	0. Clear. Fog on the ground.
„ 10 14	P.	67	V_2.																					
„ 10 21	P.	84	V_2.	......	...	......	...	1·																
„ 19 7	...	......	...	......	...	......	...	......	30·327	43·2	30·352	......	27·8	27·8	......	......	......	......	......	......	......	S.W.	350	9. Cirrostrati. Cirrocumuli.
„ 19 10	P.	78	V_2.																					
„ 19 32	P.	79	V_2.	......	...	......	...	10·																
„ 20 14	...	......	...	......	...	......	...	......	30·328	42·7	30·354	......	28·2	......	......	......	27·8	......	......	......	......	E.N.E.	100	9. Cirrostrati. Cirrocumuli.
„ 20 18	P.	85	V_2.																					
„ 20 32	P.	90	V_2.	......	...	......	...	6·5																
„ 22 0	...	......	...	......	...	......	...	......	30·318	43·6	30·340	26·1	32·4	31·7	0·7	31·2	......	102	......	......	......	N.N.E.	50	7. Cirrostrati. Cirrocumuli; slight fog.
„ 22 3	P.	112	V_2.																					
„ 22 19	P.	97	V_2.	......	...	......	...	6·5																

vations recorded in the Journal between September 10 and 30, is about four. These were generally made at about 9 and 11 A.M., and 1, 3 and 5 P.M. The daily mean number between October 1 and March 28 is nearly six, usually made at about 7 and 10 A.M., and 1, 4, 7 and 10 P.M., at about one hour after sunrise and at about sunset.

The mean number of daily compound observations recorded is, from September 10 to 30, about three, and from October 1 to March 28 about five; the highest monthly mean is seven (in October).

Some of the circumstances which have operated to prevent the chosen number of eight daily observations having been *uniformly* completed, were,—absence of flame in the lantern occasioned by high wind, &c.; great and irregular disturbance of the pendulums of the electrometers occasioned by dust, &c. injuring the insulation, violent wind suggesting the caution of securing the conductor from damage by means of stays (of cord) attached to it; violent wind and rain; the necessary absence of the observer; and the intervention of Sundays (but even on these days three observations have been almost constantly made at about 7, 9 and 10 A.M.).

Five instances only are recorded of absence of signs, but the gold-leaf electroscope was not used. These were—on January $9^d\ 20^h\ 50'$, on March $5^d\ 1^h\ 0'$, on March $5^d\ 3^h\ 57'$, on March $10^d\ 4^h\ 4'$, and on March $19^d\ 3^h\ 57'$. and were marked cases of disturbance. In two or three of these instances the circumstances of weather were precisely those in which the atmosphere itself has been commonly believed to be totally uninsulating, viz. those of great and *long-continued* humidity. On March 10 the readings were high and negative in several observations before that at $4^h\ 4'$, and positive in several afterwards; a state of transition *might* therefore have existed at the observation at $4^h\ 4'$*.

Some of the above-mentioned circumstances have operated much more frequently in unfitting a compound observation for employment in the frequency deductions (entered in column I.), than in preventing an observation entirely; and some even of those entries were obtained under circumstances of weather, conditions of the apparatus, &c., which render them somewhat objectionable in discussion.

This (so-called) Frequency course terminated, necessarily, at the end of March (in order that the Magnetic course might commence (on April 1)); but between April 14 and May 14 about forty single electrical observations, accompanied by others for pressure, temperature, &c., as above, were recorded at rather irregular intervals; most frequently at about 10 A.M., 4 P.M. and 10 P.M.

III. EXPERIMENTS, &c.

The principal operations, &c., of which I set down a brief summary under this head, scarcely commenced before September 1850. A classified statement may perhaps be found more convenient than an enumeration of them in the exact order of their dates would have been.

Horizontal-force Magnetograph.

On August 31, 1850, this instrument was rendered more sensitive than it had

the "frequency paper," and employed in deducing the value, in inverse proportion, of frequency set down in column I. (*vide* p. 354, *antè*).

* Rain attended the four last-mentioned observations. It may possibly have fallen from a neutral part of a cloud or stratum, electrified by induction, and may *not* have acquired a sensible charge in its descent.

hitherto been, by substituting one of the smaller pulleys, *i. e.* No. 9 (s^6, Plate IV., Report for 1849), diameter 0·464 inch, for that before used, *i. e.* No. 12, diameter 0·614 inch, and by making the interval at the upper ends of the wire(s) less than this quantity. A still smaller pulley (*i. e.* No. 8) had been tried with parallel wires, and found to be too small (thus used) to allow the magnet to be placed at right angles to the magnetic meridian. The adjustments were made by means of the torsion apparatus (S), and by using the image of the slit in the moveable shield (b^1), projected upon ground glass at the mouth-piece (E).

On September 2, a very unsatisfactory mechanical agitation of the magnet was evinced by the photographic curve; and on the 5th some additional precautions were taken to prevent the interference of air-currents with its natural motions.

On September 7, the instrument having still exhibited symptoms of disturbance, evidently not magnetic, was rendered less sensitive, by placing the upper ends of the wire (s^6) at an interval of 0·51 inch from each other. The angle of torsion was thus reduced by 21°, 19° more than it had been before August 31.

On September 19 and 20, new adjustments, &c. were made. The angle of torsion was fixed at 52° 25′, and the arc value of 1 inch, or 50 divisions of the ordinate scale (fig. 2, Plate XXI.), was found to be 109′·6; or the arc value, in parts of the whole horizontal force of the ordinate for $\frac{1}{50}$th of an inch, was =0·00049. On this occasion "a scale was drawn on gelatine paper, one division being made equal to $\frac{1}{12}$th of an inch, and placed beside the ground surface of glass in the camera sliding-frame" (H).

On the 26th, a little adjustment of the shields took place.

In October it was worked with some regularity. [A specimen of October 16 is reserved.]

On the 5th it was found that the time of the passage of a given point on the Daguerreotype plate over the aperture of the mouth (at E) was about 2 minutes*.

On November 1, it was minutely inspected by Colonel Sabine and some further adjustments were made.

On the 15th, Dr. Faraday visited the Observatory and recommended the use of the very broad damper alluded to at p. 351, *antè*.

On December 14, experiments were made in Dr. Lloyd's manner for determining its temperature corrections; when eight observations at the mean temperature of 55°·3 gave 0·000312, and eight observations at 76°·7 gave 0·000344.

On January 10, 1851, the new broad damper was affixed.

Between January 20 and March 20 it was worked pretty constantly. New adjustments and determinations of its coefficients were made on the latter day, when the magnifying power of the lenses was found to be 3·46 times (by means of the apparatus described at p. 352, *antè*), and the distance from the axis of motion of the magnet, &c., to the moveable shield (b^1) was ascertained (by direct measurement) to be 9·08 inches; consequently the arc value of 1 inch of the ordinate scale was, as stated, 109′·4 (p. 351, *antè*).

At the end of March the screens were attached at the object-end of the camera, and a thermometer (by Adie) was inserted in the magnet case (V). The temperature of the air of the magnet case without these screens was

* Which is a *very* much longer period than that formerly occupied by such transit.

raised about 4° by the heat of the lamp. It was found that the time of passage of a given point over the aperture of the mouth was about $1\frac{1}{4}$ minute.

On April 1 at M. it was put in motion for the due prosecution of the proposed experimental trials.

About the 2nd of May a cessation of its activity occurred for two days, spent in minor improvements, as that of substituting the larger thermometer by Cary, for that previously used, &c.

From April 1 to this time, *i. e.* July 1, the thermometer has been read at intervals of about three hours.

The Daguerreotype curves, &c. produced *daily*, with the above-mentioned exception, from the commencement of the series of trials to the present time by means of this instrument, have almost constantly afforded means of measuring ordinates (in the manner described at p. 9 of the Report for 1849) to $\frac{1}{500}$dth of an inch, and generally of describing clear gelatine tracings (in the manner alluded to at p. 185 of the Report for 1850).

Vertical-Force Magnetograph.

In September and November 1850, drawings and instructions were given to Mr. Ross, Mr. Barrow, and others, for constructing principal parts of this new instrument; preparations were made for its reception; and work on it proceeded here.

On December 14, its magnet, &c. having arrived, experiments for determining its temperature coefficient were made at the same time as, and in like manner to those on the horizontal-force magnetograph; when nine observations, at the mean temperature of $50^{d}\cdot4$, gave $0^{d}\cdot000283$, and 11 observations, at $71^{\circ}\cdot5$, gave $0^{\circ}\cdot000319$.

On the 21st Mr. Ross's part arrived.

On February 8, the apparatus described at p. 352 having been completed, observations were made to determine the magnifying power of the lenses, and to examine the effect of distortion by its means. The results from two series of observations were, that the magnifying power was 3·81 times, and that "the aberration was very small, so small indeed as to render it uncertain whether the image, in the middle of the field, was greater or less than at the ends; the whole amount of apparent difference being quite within the probable error of observation." In this case the ground glass plate, at the mouth (E), was divided to $\frac{1}{5}$th of an inch*.

On February 10, it was ascertained that no sensible difference in the Daguerreotype impression was produced by enlarging the aperture at the object-end (C) of the camera.

On February 24, measurements were made to ascertain the radius, viz. 11·9 inch, from the knife-edge to that part of the slit in the moveable shield (o^{1}) which corresponds with the moveable image in the conjugate focus at the mouth-piece (E), by means of the instrument described at p. 352, *antè*.

On the 25th this magnetograph was mounted upon its corbels (in the quadrant room) and partially adjusted for work.

On March 3, the transit of a given point of the Daguerreotype plate over the mouth (at E) was made to occupy $1\frac{1}{2}$ minute.

On the 10th it was ready for further trials, and on this day a good curve was produced; but soon afterwards (on the 19th) we found that the curves

* The spherical aberration of the lenses was not examined.

were gradually (and bodily) approaching the zero-line. It was therefore examined by the maker of the magnet himself, who could see nothing in the disposition of the other parts to prevent the proper action of the magnet. The screen for preventing the bad effect of heat from the lamp was applied (as to the other force instrument), and the slit in the moveable shield (b^1), having been found too narrow, was widened.

On the 31st it underwent adjustments and examinations which we hoped would be final. The radius was found to be 11·93 inches (as on the 24th inst.). The magnifying power of the lenses was 3·78 times, as ascertained by the method described above. The arc value of 1 inch of the ordinate scale was consequently 76′·23. The time of vibration (viz. 17·9 seconds) in a horizontal plane, at a temperature of 52°, was determined by suspending it, protected from currents of air, from a solid support by a small silken thread, and by using a microscope with cross wires, to view a mark on the shield (b^1). Its time of vibration in a vertical plane, viz. 20 seconds, at a temperature of 53°, was determined, by observing the oscillations of the *image* of the slit at the mouth-piece (E) and the chronometer. The time of transit of a point of the plate over the mouth was found to be about $1\frac{1}{4}$ minute.

On April 1 at M. it was brought into activity for the "trials;" but the curve soon began to exhibit great dislocations, and also the former tendency to approach the zero line. A condensing lens was afterwards mounted in front of the camera (A), in order that the lamp might be removed to a greater distance from it; but dislocations, &c. in the curve gave evidence of mechanical vibration having occurred at the times of putting the plates into the slider-case (F) and removing and replacing the lamp, *i. e.* at sunrise and set, and we believed it *possible* that some cause of unsteadiness might still exist in the mountings, particularly in the brass pillars (Q). These were therefore discarded, *for the present*, and the intermediate corbel was very firmly planted and cemented upon the plinth of the quadrant-wall to supply their place. The whole stone and marble-work was rendered as secure against vibration as an experienced mason could make it. The magnet had altered its time of vibration in the vertical plane to 10 seconds, and various changes of this kind have since occurred (as stated).

On the 9th the time of transit of a point of the plate over the mouth was $1\frac{1}{2}$ minute.

On May 2, the larger thermometer having been substituted for a smaller, it was deemed ready to resume its functions; but, on the next day, dislocations, &c. corresponding with the usual times were shown by the curve; thus rendering it highly improbable that *instability* of the four very stout pillars (Q) or of any fittings had produced the bad effect.

On the 5th this conclusion was confirmed by discovering that the dislocations were occasioned, principally, by the removal of the soft iron bars of the neighbouring window-shutters, from a vertical to a horizontal position, and *vice versâ* at the above-mentioned periods (a precisely similar case to one which had long since occurred relatively to the declination instrument, and had been forgotten). The bars were therefore now (as was one bar formerly) discarded. After this time the great dislocations ceased; but a few instances have since arisen of extremely sudden variations in the curves *of all the magnets simultaneously*, which might have been mistaken for mechanical disturbances, if they had not been simultaneous; and some other small dislocations of these vertical-force curves evince unnatural motions of the magnet.

On June 4 it had altered its time of vertical vibration.

The daily Daguerreotype impressions have been almost equal in *sharpness* to those of the horizontal-force instrument. But there still exists some imperfection (probably in the knife-edge) requiring attention.

Declination Magnetograph.

In March 1851, some of the improvements, described at p. 350, *antè*, on this old instrument (*vide* Pl. XI. Phil. Trans. Pt. I. for 1847), were executed here.

On the 26th it was carefully examined. The wedges were tightened and the camera (A), &c. were adjusted, by turning them through a small arc upon the axis of the suspending skein, so as to cause the *image* of the zero slit in the fixed shield to occupy its proper place at the mouth (E) on the ground glass scale (or on the silver plate or Talbotype paper)*.

On the 27th, 29th and 31st, further examinations and adjustments were made. The suspending skein seemed to have remained nearly unaltered, since 1846, as to the condition of its fibres: a torsion of 10° only existed (which was eliminated in the computations), but the effect of a twist given to it =90° of the torsion circle displaced the magnet a quantity =44°. The distance from the axis of motion to the moveable shield (in the place of b^1) was 18 inches. The magnifying power of the lenses was =6·706 times (as ascertained by the means described at p. 352). The arc value of 1 inch of the ordinate scale, when corrected by the torsion coefficient, was 28°·71.

On April 1 at M. it was put into activity for the "trials," and, in the course of this month, several little improvements (not affecting its indications) were made.

On the 29th it was found that, in consequence either of the fixed shield having descended or of the moveable shield having risen, light had passed between the edges of them to the photographic plate. The delay of a day was therefore required, in order to remedy the evil, by lengthening the zero slit in the mouth-piece, and lowering the moveable shield a very little. These expedients answered the purpose at that time, but similar faults required several repetitions of the last-mentioned process afterwards; therefore,

On June 14, the wooden bearers (X) were raised, and four perpendicular supports of straight-grained deal, resting upon the rafters below, were placed under them. This expedient will not, probably, secure the instrument against errors arising from the use of *wood for bearers, fittings*, &c., and perhaps the expansion and contraction of the skein.

It has nevertheless generally presented us with curves, measurable to $\frac{1}{200}$dth of an inch at least. The exceptions occur in a few instances of magnetic disturbance. The damper (a *narrow* one composed of wood with a coat of copper electrotyped upon it) seems to have little effect.

Tabulating and Tracing the Magnetic Curves.

Colonel Sabine has in his Report (*ante*) clearly and ably described the nature and modes of procedure which have been carried out, by Mr. Welsh, relative to these operations; and the apparatus employed has been detailed at p. 84 of the British Association Report for 1849.

* In 1846 a similar kind of adjustment was made, which suggested the possibility of adapting apparatus of telescope, &c. to a metallic camera, &c., which might be moved about the axis of the suspending skein in the manner of Colonel Beaufoy's variation transit-box, and thus become a means of procuring self-registered curves of *absolute determination*, if it were desirable.

The number of daily curves tabulated and traced before the experimental trials commenced on April 1st, is not considerable. The number since then to the present time is about 200.

It only remains here to annex lithographed specimens of printed curves and their abscissæ (or zero lines), Plate XXIII., which specimens were printed in the manner described at p. 353, *antè*. It is not pretended that the lithograph is equal, in sharpness and accuracy, to the original impression from the gelatine. It is made use of merely because a sufficient number of impressions for this Report could not be obtained probably from the gelatine.

Impressions made in September from the gelatine on India-paper, were very good; but the use of bank-note paper was preferred, on account of its very superior toughness and less liability to adhere to the gelatine under the press. The impressions on bank-note paper were very nearly equal to the India-paper impressions. The number which could be "pulled" from the gelatine itself would be ample for distribution to other observatories, &c.

On February 18, a specimen of the action, on *Talbotype paper*, of the horizontal-force magnetograph sent to the Toronto Observatory, arrived here. About half of the curve had been produced by day-light and the remainder by lamp-light. The outline, as viewed by the naked eye, seemed tolerably well defined (in both cases); but when examined under the same magnifying power as that used in tabulating the curves received upon silver, was found to be much less perfect than in these curves: it exhibited a little fringe, evidently due to the spongy texture of the paper, and was quite inadequate to measurements, equally minute, with those of lines received upon a silver surface*.

The Magnetographs and Magnets in general.

In September 1850, it was ascertained that the cost of Lucca oil consumed in the Rumford polyflame lamps used with these instruments, was about 0·8 penny per hour for each.

In December, and at long intervals subsequently, the improvements upon the sliding-frames (H), as regards the scales (*vide* p. 350), were prosecuted. The first were engraved by Ross with a diamond point.

By the end of March it had been found that the etching process, by means of hydrofluoric acid, produced scales on the ground glass well-adapted to the purposes; and the dividing machine of M. Perreaux was very advantageously employed in this operation.

On January 24, Mr. Welsh explained his plan for applying his sliding rule system to computations relative to magnetic curves.

About June 15 a working drawing of the dip and total-force sliding-rule was made. It was put into Mr. Adie's hands, who constructed it in boxwood; it has, together with Mr. Welsh's description of it, been exhibited and delivered to the Secretary of the Physical Section.

In March, and subsequently, the Toronto vertical-force magnetograph was examined and corrected. [A screw had become loose and the knife-edge a little damaged.]

* I cannot help adverting here to an evident mistake in the Athenæum of July 12, 1851, p. 784, where the Astronomer Royal is made to imply that my method of self-registration does not embrace the use of the paper process; whereas it has been clearly shown that, between April 1844 and February 1849, I used no other; that specimens, so procured, have been approved by himself, and that the Kew magnetographs were always *equally applicable* to either the Talbotype or the Daguerreotype process at the pleasure of the observer or photographist. They can be as easily applied to *any* new photographic process I believe.

In June a little progress was made in the construction of a new Declination magnetograph, or rather in new mechanism, to be substituted for some parts of the old declination instrument.

From April 1 to this time, *i. e.* during the course of the experimental trials of the three magnetographs, the Daguerreotype plates prepared by Mr. Nicklin, our photographist, were put into the instruments daily, with the few exceptions stated, at meridian as nearly as possible, the exact time (by Dent's chronometer, with proper corrections) being known for each. They were inverted at 12 P.M. (as nearly as possible).

The course of experimental trials for six months was undertaken in accordance with a wish expressed by the Kew Committee. I should have been better pleased if I could have previously substituted a declination magnetograph, similar in general construction to the horizontal-force magnetograph, instead of the original instrument set up before many of the improvements since adopted had been made, and if I could have attempted other improvements on all the magnetographs (as that of substituting pointed for rectangular magnets, in order to diminish the time of vibration, &c.). The Royal Society granted me, in the kindest manner, a sum not exceeding £100 to be applied to the costs attending the trials, of which sum about one-third has been expended (and an exact account with vouchers maintained).

Thermometers.

On September 21 and 23, comparisons of Newman's standard thermometer were made with various thermometers; their index corrections are recorded at pp. 342 and 343.

On February 22, the dividing machine by M. Perreaux, together with the adaptations and other thermometric apparatus of M. Regnault's (alluded to at p. 346, *antè*), arrived, and soon afterwards Captain Lefroy gave some explanations concerning the former, and made satisfactory trials of their applicability to the accurate calibration and division of thermometer tubes. In these and subsequent trials a diamond point was sometimes used, and when the etching process, by means of hydrofluoric acid, was preferred, some difficulty occurred as to the choice of a proper "ground." Oil of Spike (lavender) was found to answer the purpose tolerably well. An incomplete attempt was made to etch plates of glass by Fluorine gas. Some tubing, entirely of vulcanized India-rubber, was advantageously substituted for the original tubing compounded of this material and glass in the operation of moving the calibring mercury in the thermometer tubes*.

On February 23, the maximum Rutherford thermometer (F) was found to have been destroyed.

On April 3, the Sub-committee of the Kew Observatory, appointed to direct the construction and verification of standard thermometers, &c., made experiments for determining the freezing- and boiling-points of a standard thermometer of M. Regnault, No. 229, or Woolwich standard, which Colonel Sabine brought (with another by Ronchetti); also of the standard Regnault, No. 231 (or Kew standard). The freezing-points of the above Ronchetti, Newman's standard (C), the immersed thermometer in the improved Regnault hygrometer, and the immersed thermometer of the new Daniel hygrometer, were also determined. The apparatus used was a part of that referred to at p. 346, and the results obtained are already stated, excepting that the boiling-point of the Regnault No. 229, or

* A further improvement for effecting this object is contemplated.

Woolwich standard, was at 578·1 div., and its freezing-point at very nearly 92·1 div., and that the barometer reading, reduced to 32°, was 30·093 inches, and the temperature of the room about 55°.

In June considerable progress had been made in calibring, graduating, &c. thermometers as standards; some tubes having been selected with great care for this purpose, and about six complete standard instruments have been made.

Hygrometers, &c.

On September 18, 1850, experiments had been made for testing the Saussure eight-haired hygrometer*. It had been placed in a receiver, first with chloride of calcium and then with water. After several trials and adjustments of the instrument, the result was that "dryness" corresponded to −5 degrees of the scale, and "humidity" to 105, the temperature during the experiment being about 62°.

In this month arrangements were made for some experiments on tension of vapour, according to Mr. Broun's method. A little apparatus was afterwards constructed and some progress made.

On the 18th, Captain Ludlow presented to us the Hygrometer and aspirator of M. Regnault† in their original forms, and made some satisfactory comparisons with the former and the Daniel; they corresponded to about 0°·2.

On October 11, Colonel Sykes went over a series of observations with Mr. Welsh of the wet and dry bulbs, and the (above-mentioned) Regnault hygrometer, and suggested a form of record for the hygrometric observations, and the use of one standard dry thermometer for those observations.

At about this time, and subsequently in examining and using this Regnault hygrometer and its aspirator, it was observed that at low temperatures an obstruction occasioned by the position of the cork would prevent the convenient reading of the immersed thermometer; that the cistern, composed of glass, united to metal by cement, was very apt to become leaky (in consequence of the great variation of temperature to which they are often subjected); that no trifling waste of æther was occasioned by decanting this expensive material from one vessel to another at each period of observation; that no line of demarcation (as in the Daniel) assisted the precise observation of the dew-point moment; and that the aspirator required to be refilled with water, at, sometimes, a very unseasonable moment, and always with waste of time, &c.

On November 15, drawings illustrating a proposal for methods of obviating these inconveniences, &c. were made and submitted to Colonel Sykes's consideration, and his approval was the inducement for giving instructions (on November 26) for constructing a new instrument.

It arrived at the end of February, and early in March, having been found to answer the intended purposes well in most respects, was brought into use. Subsequently various little ameliorations have taken place which have brought it to the state already described‡.

On October 25, a drawing of the parapet in front of the door of the North Hall was made for the guidance of M. Regnault in constructing his dew-point apparatus for Kew.

On Jan. 14, Mr. Welsh made a full description and diagram of his hygrometric sliding rule.

* *Vide* p. 343, *ante.* † P. 343, *ante.*

‡ P. 343, *ante.* An apparatus of the kind has been also made by Cary for St. Mary's Hospital by Dr. Ansel's desire, and others are to be made for Professor Forbes, Mr. Dixon, and other gentlemen.

On the 18th, Colonel Sabine examined and highly approved of the invention: between this time and the end of June the standard scale, of German silver, used in its graduation, was divided by means of M. Perreaux's engine, and the rule itself was completed by Mr. Adie in box-wood. The instrument was in June sent to Ipswich for exhibition to the Physical Section, together with a description of it, and both have been delivered to the Secretary of the Section.

On May 16, experiments were made by and in presence of Colonel Sykes and Captain James, R.E., for testing the action of the improved Regnault hygrometer, and for other purposes. These experiments formed five series; but there being some reason to suspect an error in the observation of the Regnault in the first series, it was declared to be not "trustworthy," and the last having been made by a gentleman visitor, not accustomed to observations of this kind, should not perhaps be included in the following summary.

Two series were made in the North Entrance Hall, where the atmospheric temperature fell, during their continuance, from 62° to 61°, and the barometer stood at 30·018 and 30·14 corrected.

The general result of these two were, that the observed dew-point of the Daniel hygrometer was 0°·4 lower than that of the Regnault, and that the dew-point by the wet-bulb hygrometer, as reduced by Dr. Apjohn's formula, was 1°·5 higher than that of the Regnault, and as reduced by the use of Mr. Glashier's factors, 2°·55 higher.

Two series were made on the platform (in open air) in front of the North Hall, where the temperature fell from 60°·9 to 59°·6 during their continuance, and the barometer stood at 30·01 in.

The general results of these were, that the observed dew-point, by the Daniel and the Regnault, exactly coincided, and that the dew-point by the wet bulb, using Apjohn's formula, was 1° lower than that of the Regnault, and using Glashier's factors, 2°·75 higher.

The dew-point *apud* Apjohn was computed by means of Colonel Boilieu's tables.

The lowest temperature which we could procure by the action of the Regnault was 16°, and by the Daniel 41°. The atmospheric temperature was 62°. (but previous and subsequent trials gave a much greater difference).

An experiment was made in the North Hall, at the suggestion and by desire of Colonel Sykes, to ascertain the difference between the indications of the dry and wet thermometers when at rest, and when put into rapid motion, by whirling them, attached to a line held in the hand, through the air. The motion produced no sensible change on the dry, but a difference of −0°·9 on the wet. Precautions having been taken to obtain accurate readings, the dry, *before* the motion, stood at 61°·8, wet 52°·8, dew-point computed 44°·4, observed 42°·4; the dry, *after* the motion, read 61°·8, wet 51°·9, dew-point computed 42°·2, observed 42°·4.

Between the end of September 1850 and this time, many comparisons, observations and remarks have been made relative to the Wet-bulb, the Daniel and the Regnault hygrometers, "chiefly with the view of ascertaining to what extent the indications of the Wet-bulb, as commonly observed, are to be depended upon."

"The number of comparisons with Daniel's hygrometer has been somewhat above 500, and with Regnault's about 270," in which all the corrections for index errors, the computations (by Apjohn's formula, with the use of Colonel Boilieu's tables), and the requisite observances for attaining accuracy were made.

The details will be stated when these, together with additional comparisons, shall have received more complete discussion than they yet have.

The following experiments and remarks were made in the course of these inquiries, &c.

Instead of taking the mean between the reading of the immersed thermometer at the first appearance of dew on the bright bulb of the Daniel, and the reading at the time of its disappearance for the determined dew-point, in order to eliminate the error which might arise in the estimation of the dew-point from the continued fall of the thermometer after the first appearance of dew, the observer checked the internal evaporation from the æther in the bright bulb, " whenever the dew has shown itself by touching with the hand the covered bulb (upon which the æther is poured), and thus preventing an undue accumulation of water" on the bright bulb, and giving time for the mass of æther, the immersed thermometer and the bulb itself to acquire a uniform temperature at the dew-point moment.

In the cisterns of the Regnault hygrometers, the continual agitation of the æther (by the passage of air bubbles through it) served to produce the requisite uniformity of temperature throughout the mass of æther and the bulb of the immersed thermometer.

In experimenting with the improved Regnault, the difficulty alluded to at p. 345, of "catching the exact instant of the formation of dew," was not found to have been completely obviated by the method there described*. But " the agreement between the two dew-point instruments is generally good, the discordance rarely amounting to one degree; the dew-point by Regnault being generally somewhat lower than by the Daniel."

" The expenditure of æther is somewhat greater in the Regnault than in the Daniel, which however may perhaps be compensated by the inferior quality consumed."

Experiments similar to those made on May 16 (*vide* p. 366, *antè*), on the effect of a current of air on the wet bulb, " have been repeated several times since, and always with a like result. It has also been found that a moderate agitation of the air produces the maximum amount of depression. Similar results have been found in the ordinary comparisons in the open air; the agreement between the computed and observed dew-points being greater when a moderate wind was blowing than when the air was still."

Barometers.

Between September 23 and November 16, 1850, a series of 167 comparisons was made between the mountain barometer and the photo-barometrograph; " but as there can be little doubt that considerable discrepancies which the comparison showed might be partly owing to the imperfect standard of comparison employed, no confidence is placed in the results from this series."

In October Colonel Sykes recommended the acquisition of a good standard barometer.

In January the standard barometer of Newman (*vide* p. 346, *antè*) arrived from Colonel Sabine, and soon afterwards, by his desire, its new attached thermometer was added.

Between January 23 and March 30, about 200 comparisons, &c. were made between this barometer and the photo-barometrograph; the principal results of which were, that the range upon the Daguerreotype plate (at E,

* Further trials on this point are in progress.

fig. 1, Plate XXII.) of the image of the surface of the mercury in the tube (at b^1) is rather more than twice the range of the mercury itself; that the compensation was overdone by about $\frac{1}{20}$th of the whole amount; and that the mean error of an observation, from a whole series of 181 comparisons, was 0·0028 inch. It was thought "only fair to suppose that a portion of this mean error is to be ascribed to the standard barometer;" and I fear a portion may be attributed to dry rot or other cause of infirmity in the flooring of the quadrant-room, that end of the frame-work (P) which carries the barometer being much nearer to the wall of the building than the image end. "The comparisons do in fact exhibit some symptoms of alterations in the floor."

These comparisons, and the numerous computations, &c. required, were made with great care, and yield a very satisfactory general result. "An error of 0·002 inch in an observation would not be greater than might be expected in a standard barometer*."

Anemometer.

On September 27, Mr. Howlet, of the Ordnance Office, brought an experimental anemometer for comparison with our balance anemometer (*vide* p. 341, *antè*), and for examination.

It was speedily erected upon the leads at the southern end of the observatory, and the action of both instruments was watched during about half an hour. The mean result was, that the former gave about one-tenth more for pressure of wind than the latter.

At Mr. Howlet's request, a note was addressed to Sir John Burgoyne, in which I expressed an opinion that an instrument of the kind, exhibited by Mr. Howlet, might answer the purpose of a portable anemometer, applicable in the intended manner, if properly constructed.

Mr. Howlet made a sketch of his model, and left it at the Observatory.

IV. MISCELLANEOUS MEMORANDA.

On September 12, 1850, Mr. Jesse (of the Woods and Forests) visited the building, and promised to represent its state as regards dry rot, &c.

On October 5, an interesting account of an Aurora Borealis, which occurred on the evening of the 2nd, was received from Mr. Gassiot, who, with some friends, had carefully observed it at Clapham Common. The direction in which it appeared was from N. by W. to N.N.W. by compass. Mr. Gassiot's letter was copied in our Diary.

On November 5, Professor Graham came to confer about methods of transporting air, free from town contamination, for chemical analysis, with reference to the presence of ammonia, from this locality to the London University. Every means in our power, calculated to facilitate Dr. Graham's important researches, were (of course) tendered with great alacrity and pleasure †.

* If the instrument were mounted in as substantial a manner as are the horizontal and vertical-force magnetographs, and if a compensating apparatus of *larger* zinc rods and stout glass tubes were substituted for this of small rods and *wood*, the error of an observation would probably be less, and even the remaining error might perhaps be almost got rid of *by making use of the micrometer screw* (at b^{14}), provided expressly for preventing the compensation from being either "overdone" or underdone. The neglect of doing this is entirely my own.

Since the above was written an instrument improved as above has been ordered by Mr. Johnson for the Radcliffe Observatory.

† The aspirator (described at p. 344) would probably be found convenient in cases of this kind.

On the same day and subsequently, a few experiments were commenced on M. Claudet's actinometer.

On January 20, 1851, Mr. Phipps (of the Woods and Forests) examined the building; when its state, as to dry rot, &c., was represented, and an intimation was made that probably Lord Seymour would visit it.

On the 25th, Professor Potter's "Aërometric Balance for measuring the density of the air in which it is situated," arrived for examination and experiment, but was required to be returned before any results which could be confided in were obtained. The difficulties of observing the instrument under unobjectionable conditions seemed almost insurmountable. It is described in the Philosophical Magazine, vol. xxxvii. p. 81.

On May 8, Lieut. Fergusson, of the Indian Navy, began a little course of study and manipulation relative to all our methods of procedure in the self-registering system, and in eye observations of atmospheric electricity, &c. It was continued daily during about two weeks, at the end of which time he had become well qualified to prosecute and conduct such operations and observations.

At the end of May, Mr. A. Broun, late Director of Sir Thomas Brisbane's magnetic observatory, appointed to the Trevandrum observatory, commenced a similar course, which lasted (at intervals) about 2 weeks, and terminated with like success*.

On June 20, Colonel Sabine and Professor Stokes decided upon using the South Lower Hall for the prosecution of Professor Stokes's proposed experiments to determine the index of friction in different gases.

On the 24th, Mr. Weld, Assistant Secretary of the Royal Society, visited the Observatory, and informed me that he was directed to send a large quantity of apparatus belonging to the Royal Society to be deposited here. He examined the localities in which they could be properly lodged, viz. the glass cases, &c., formerly occupied by His Majesty George the Third's splendid collection of instruments of a similar kind; and on the 26th, many cases containing the Royal Society instruments arrived; but the operation of unpacking, &c. was deferred to an early day after this meeting of the British Association.

Some boxes (probably containing papers) locked and without keys, arrived with the instruments and were not opened.

Between this time and the end of the month all outstanding bills due by the establishment were paid, excepting three or four very small accounts (which presented a little difficulty in adjustment, &c.); and a tabulated statement embracing the whole expenditure and receipts for the (British Association) year was delivered to the Kew Committee, by which account it appears that the total sum expended on the *Establishment account* has been £309 2*s*. 2*d*. (including the above-mentioned small accounts), which sum is £29 13*s*. less than the amount of the grant made at the Edinburgh meeting on August 1, 1850, added to the residue of the former grant made (in 1849)†.

In the course of the year numerous meetings of the Kew Committee, and very many individual attendances of its President, Colonel Sykes, Colonel Sabine, and Mr. Gassiot, have taken place at the Observatory.

Our visitors have been numerous, and almost exclusively gentlemen of high scientific reputation.

* An electrical apparatus of the kind described at p. 339, *antè*, has since been put into course of construction for Mr. Broun.

† The sum annually expended has always been somewhat less than the grant and residue; sometimes considerably less.

I have great pleasure in bearing testimony here to the general services of Mr. Welsh, and particularly in making and recording, in the Diary, &c., very numerous comparisons, observations, measurements, adjustments and computations relative to the thermometers, the various hygrometers, the barometers and barometrograph, and the magnetographs*, in the laborious processes of tabulating and tracing the magnetic curves, and in making and recording all the observations and remarks entered in the form of the Electro-meteorological Journal; in suggesting a few alterations in that form, and in the mode of deducing the value of electrical frequency (*vide* p. 355); in pointing out the former defective mode of suspending the mountain barometer, and the first-mentioned inconvenience in the use of a Regnault hygrometer (*vide* p. 365); in suggesting the use of screens to protect the magnets from the heat of the lamps, and in assisting me to vary the older methods of ascertaining the magnifying powers of the lenses of the magnetographs (*vide* p. 352).

The calibrations and graduations of the new Standard Thermometers have been executed by him.

Ordnance Survey of Scotland.

The Committee appointed at the Edinburgh Meeting in 1850, "for the purpose of urging on Her Majesty's Government the completion of the Geographical Survey of Scotland, as recommended by the present Meeting of the British Association at Edinburgh in 1834," presented the following Memorial to the First Lord of the Treasury:—

"My Lord, "London, February 17th, 1851.

"As constituting a committee appointed for that purpose by the British Association for the Advancement of Science, we beg to call your Lordship's attention, and that of Her Majesty's Government, to the untoward condition and slow progress of the Geographical Survey of Scotland.

"In the year 1834, when, for the first time assembled at Edinburgh, the British Association prayed the Government of that day to accelerate materially the completion of a work, which, notwithstanding that the primary triangulation was commenced in 1809, had not produced in the intervening 25 years a single practical result. It was then shown, that the grossest errors pervaded every known chart and map; and although, thanks to the zeal of the Hydrographer of the Navy and his surveyors, many of the chief headlands have since been laid down, the mass of the land still remains in the same unsurveyed condition.

"In fact, on returning to Edinburgh last summer, after an interval of 16 years, the British Association deeply regretted to learn that, excepting Wigtonshire, about a sixtieth part only of Scotland, no portion of the kingdom had been mapped.

"Permit us to remind your Lordship that, although in consequence of many subsequent appeals from other public bodies (including the Royal Society of Edinburgh and the Highland Society), the Government did at length, in 1840, direct the survey to be laid down on a scale of six inches to a mile, or similar to that of the Irish survey, so feeble and inadequate has been the force employed, that in judging from what has transpired since that date,

* Which comparisons, &c. are far too numerous and complex for insertion in a summary of this kind.

upwards of 50 years must elapse before the map of Scotland can be completed.

"It is to this point that we specially call your Lordship's attention.

"The people of Scotland naturally feel that they are entitled to equal justice with the inhabitants of any part of the United Kingdom, in respect to a work on which, as a basis, all improvements in agricultural, engineering and mining affairs are so intimately dependent. Under this feeling, and with a strong sense of the value and importance of this work to all interests in their country, they cannot but observe that whilst the map of Scotland has thus been almost in abeyance, and that 66,000*l.* only has been expended on it during the present century, Ireland actually obtained a complete survey and map in the space of 20 years, and at an expenditure of 820,000*l.* sterling.

"Documents, a table and references to parliamentary data are annexed, to sustain our statement, and to enable your Lordship to see what amount of expenditure will suffice to bring Scotland into a position which has been long ago attained by even small and poor states on the Continent.

"We, therefore, implore your Lordship, and Her Majesty's Government, to endeavour to obtain from the Parliament an annual grant, adequate, if possible, to the completion of this map within the next 10 years, for we are confident that the appeal we have ventured to make is in unison with the earnest wishes of all classes of the people of Scotland.

"We have the honour to be,
"My Lord,
"Your Lordship's most obedient Servants,

(Signed) "ARGYLL.
BREADALBANE.
DAVID BREWSTER.
RODERICK I. MURCHISON.
JAMES FORBES."

The Memorial to Lord John Russell was backed in the following manner by the undermentioned proprietors, and would have been supported by many more had it been circulated after it obtained their signatures: "We, the undersigned proprietors in Scotland, do cordially approve of the annexed appeal of the British Association for the Advancement of Science, and beg to express our earnest hope that Her Majesty's Government will accede to the very reasonable request which is loudly called for by all persons in North Britain:—

(Signed) "RICHMOND.
EGLINTON and WINTON.
F. F. HAMILTON.
WM. ALEX. ALEXANDER.
CAWDOR.
JOHN HALL, of Dunglass.
G. GRANT SUTTIE, of Preston Grange.
MINTO.
W. GIBSON CRAIG.
BUCCLEUCH, &c.
ROXBURGHE."

Sir Roderick Murchison, as convener of the above-mentioned Committee of the British Association, reports, that a Committee of the House of Commons having adopted the views advocated by the British Association, the Parliament has since granted the sum of £25,000 per annum for the exe-

cution of the Map of Scotland on a scale of one inch to a mile, and that in consequence it is estimated that the whole work may be completed in 10 or 12 years.

PROVISIONAL REPORT.

Dr. Gladstone and Mr. G. Gladstone presented a Statement of the Progress made in an Inquiry on the Growth of Plants in different Gases.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Mathematics.

The Parallelogram of Mechanical Magnitudes. *By* Homersham Cox, *B.A.*

The following six kinds of magnitude considered in mechanical science,—

Of translation—	Of rotation—
Statical forces,	Statical couples,
Linear velocities,	Angular velocities,
Linear accelerations,	Angular accelerations,

all conform to the remarkable and well-known law, that if two sides of a parallelogram represent the magnitude and direction of two components of either kind, their resultant is similarly represented by the diagonal.

It is here proposed to show that this law may be proved for the six kinds of magnitude indifferently by a method of demonstration common to them all. It is clear that such a demonstration can be derived only from fundamental principles common to them all, and it is very interesting to trace out these axioms, which may be regarded as the abstract causes of the coincidence of the laws of the effect of mechanical agents of nature so diverse as those above specified. Extraneous and unnecessary considerations, imported into the particular demonstrations, are excluded from the general demonstration, which involves no empirical axioms, and deduces its results solely from analytical and geometrical principles, and the definitions of the measures of the magnitudes considered.

The direction of a couple, angular velocity, or angular acceleration is here defined to be the direction of the axis about which either respectively tends to turn, or turns a system of material parts, of which the relative positions do not vary. The measure of the relative magnitudes of couples is the relative magnitudes of their moments. The measure of the relative magnitudes of angular velocities is the relative magnitudes of the angles through which they respectively turn in a given time, a system of material parts of which the relative positions do not vary. The measure of the relative magnitudes of angular accelerations is the relative magnitudes of the angular velocities which they respectively generate in a given time. The other terms used in this demonstration do not here require definition.

From the definitions of a Resultant, and of the measures of the six kinds of magnitude above specified, it may be shown that—

I. The resultant of components having the same direction is their algebraical sum. Therefore (II.) two equal and opposite components destroy each other's effect.

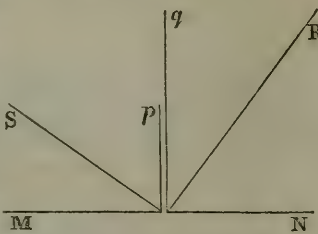
The inclination of the resultant of two components inclined to each other at a given angle is independent of the unit by which they are measured, and depends solely on their relative (not absolute) magnitude—conversely.

(III.) The inclination of the resultant of two components inclined at a given angle determines their relative magnitude.

The relative magnitude of the resultant is independent of the unit by which the components are measured. Consequently,

(IV.) Of two components inclined at a given angle, the relative magnitude determines the relative magnitude of the resultant.

Let two perpendicular components, represented in direction by M, p, be inclined to their resultant S, at the same angles respectively as two others, q, N, respectively to their resultant R.



Let M, N meet, and be equal and opposite. It is clear by the geometry that R, S is a right angle.

R, S together are equivalent to M, p, q, N, and therefore to p, q (since M, N by (II.) destroy each other's effect) : since p and q are in the same direction, $p+q$ by (I.) is the magnitude of the resultant of R, S.

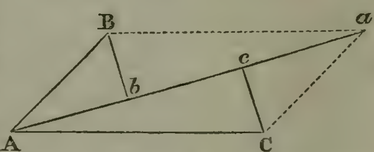
$p+q$ is inclined to its perpendicular components at the same angles as R to its perpendicular components. Hence (III.), the relative magnitude of the components, must be the same in both cases. As then these two pairs of perpendicular components have the same ratio, the relative magnitude (IV.) of the resultant must be the same in both cases, or

$$\frac{p+q}{R}+\frac{R}{q}. \text{ Similarly, } \frac{p+q}{S}=\frac{S}{p}, \therefore (p+q)^2=R^2+S^2,$$

which determines the magnitude of the resultant of two perpendicular components.

By geometry, if the square of one side of a triangle be equal to the sum of the squares of the other sides, the triangle is right-angled; therefore if a triangle have three sides representing the magnitudes of two perpendicular components and their resultant respectively, it is right-angled.

Let now A b, B b represent the magnitudes of any two perpendicular components. Therefore by the above, the hypothenuse A B of the right-angled triangle A b B represents the magnitude of the resultant.



Let A c, C c represent the magnitudes of two other components, whereof C c=B b and A c is of any magnitude whatever. Therefore A c, the hypothenuse of the right-angled triangle A C c, is the resultant of A c, C c.

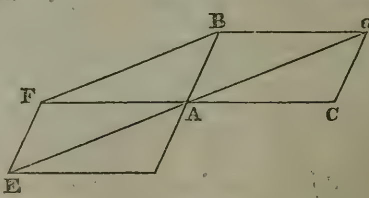
Let the directions of components equal to B b or C c meet at A and be opposite. Then these components destroy each other's effect, and there remain A b, A c having the same direction, and therefore Ab+Ac is the magnitude of the resultant of components represented in magnitude by AB, AC.

Take the straight line $c\,a$=Ab, therefore the straight line Ac=Ab+Ac. In triangles ABb, cCa, Ab=cA, Bb=Cc, angle b= angle c. Therefore AB=aC. Similarly, in triangles ACc, Bba, AC=Ba. Therefore ABaC is a parallelogram.

It is clear that AB, AC may be components of any magnitude, and inclined to each other at any angles whatever. Hence, the above determines generally the *magnitude* of the resultant of two such components.

To find the direction of the resultant.

Let AA, AC represent the direction and magnitude of the components of which the directions meet at A. Therefore by the preceding proposition, Aa represents the magnitude of the resultant. Draw in the direction opposite to that in which this resultant acts,



$$AE=Aa \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.)$$

Therefore the mechanical magnitudes represented in magnitude and direction by

AB, AC, AE destroy each other's effect . . . . (2.)

Complete the parallelogram BE,

$\therefore$ FB=AE=Aa . . . . (3.)

and by the preceding proposition AF represents the magnitude of the resultants of AB, AE.

By (2.) the resultant of AB, AE is equal and opposite to AC;

$\therefore$ AF=AC=Ba . . . . (4.)

and CAF is a straight line.

From (3 and 4) Fa is a parallelogram, and because FB $\parallel$ AD, and CAF a straight line, $\angle a$AC$=\angle$BFA. But $\angle$BFA$=\angle$FAE; $\therefore \angle$FAE$=\angle a$AC; $\therefore$ EAa is a straight line. But EA was drawn opposite to the direction of the resultant of AB, AC. This direction is therefore the diagonal of the parallelogram BC.

The theorem is therefore demonstrated.

It is clear that this general theorem may be made the common basis of the three sciences of STATICS, KINEMATICS and DYNAMICS, in the two parts of each which respectively treat of points and bodies of finite magnitude.

Summary of the Results of the Hypothesis of Molecular Vortices, as applied to the Theory of Elasticity and Heat. By WILLIAM JOHN MACQUORN RANKINE, *C.E., F.R.S.E.*

This paper gives a general view of the results of a peculiar mode of conceiving that theory which regards the elasticity connected with heat as the effect of the centrifugal force of small molecular motions. Each atom of a body is supposed to consist of a nucleus enveloped by an elastic atmosphere. The nuclei of the atoms, vibrating independently, or almost independently of their atmospheres, constitute the medium which transmits light and radiant heat. By supposing a small portion of atmosphere to form a load on each nucleus, varying in amount according to the direction in which the nucleus vibrates, the phænomena of double refraction may be explained* (see Philosophical Magazine for June 1851). The total elasticity of a body consists of two parts, one which may be resolved into forces acting along the lines joining the atomic nuclei, and which resists change of figure as well as change of volume; and another which cannot be so resolved, and which resists change of volume only (see Cambridge and Dublin Mathematical Journal for February and May 1851).

Part of this total elasticity is the pressure of the atomic atmospheres at certain surfaces which may be described round each atomic nucleus, and at which the resultant of the molecular attractions and repulsions is null. This pressure varies with heat; that is to say, it is increased by the centrifugal force of the movement of revolution of the particles of the atomic atmospheres. If v represent the mean velocity of that movement, and g the accelerating force of gravity, then $Q=\frac{v^2}{2g}$ is the quantity of heat in unity of weight of the substance.

Two bodies are said to be *at the same temperature* when neither tends to communicate heat to the other; and degrees of temperature are measured by the pressure of a perfect gas at constant volume. Let τ represent temperature, as measured from an *absolute zero* 274°·6 Centigrade, or 494°·28 Fahr. below the temperature of melting ice; then

$$\tau=\varkappa\left(\frac{2Q}{hk}+1\right)$$

$$\text{and } Q=(\tau-\varkappa)\frac{hk}{2\varkappa},$$

where $\varkappa$ is a constant, the same for all substances, but varying with the thermometric scale; h is the coefficient of elasticity of the atomic atmosphere, and k a co-

* These motions being communicated from the atomic nuclei to their atmospheres, constitute that fixed heat which gives rise to increase of elasticity.

efficient having a specific value for each substance, depending on its chemical constitution. $\frac{hk}{2\varkappa}$ is the *real specific heat*. Let this be denoted by $\mathfrak{k}$.

The expansive pressure of any substance is represented as follows:—Let V_0 be the volume which unity of weight of the substance, if in the state of perfect gas, would occupy at the absolute temperature τ_0 under the pressure unity; τ the actual absolute temperature; V the actual volume of unity of weight; A_1, A_2, &c., and f (V) certain functions of the density; then

$$\text{pressure} = P = \frac{V_0}{\tau_0} \cdot \frac{\tau}{V} \left\{ 1 - \frac{A_1}{\tau} - \frac{A_2}{\tau^2} - \frac{A_3}{\tau^3} - \&c. \right\} + f(V).$$

This formula represents perfectly the results of M. Regnault's experiments on the pressure and expansion of gases (Trans. Roy. Soc. Edin. vol. xx.).

The maximum pressure of a vapour in contact with its liquid is expressed by the formula

$$\log P = \alpha - \frac{\beta}{\tau} - \frac{\gamma}{\tau^2},$$

α, β, γ having specific values for each fluid (see Edin. New Philosophical Journal, July 1849).

If unity of weight of a substance be made to undergo the change of temperature $d\tau$ and the change of volume dV, the following is the quantity of heat which it must receive,—

$$d \cdot Q = d\tau \cdot \left\{ \mathfrak{k} + \frac{V_0}{\tau_0}\left(\frac{\varkappa}{\tau} - \frac{\varkappa^2}{\tau^2}\right) + (\tau - \varkappa) \int \frac{d^2P}{d\tau^2} dV \right\}$$
$$+ dV \cdot (\tau - \varkappa) \frac{dP}{d\tau},$$

of which $\mathfrak{k} d\tau$ alone remains in the body as heat; the rest being transformed into expansive power and molecular action. From this equation are deduced the known laws of the apparent specific heat of gases, and the velocity of sound.

$d \cdot Q - PdV$ is an exact differential. This is the algebraical statement of the law proved experimentally by Mr. Joule, of the equivalence of heat and mechanical power.

The total heat of evaporation of a liquid increases uniformly with temperature, and the rate of its increase is equal to the apparent specific heat of the vapour under constant pressure.

The apparent specific heat of a vapour at saturation is *negative*; that is to say, if vapour at saturation be allowed to expand, it must receive heat from without, or a portion will be liquified to supply the heat required to expand the rest. This result has also been arrived at by Clausius.

If a body be expanded by heat at a higher temperature τ_1, and condensed at a lower τ_0, a certain proportion of the heat employed in expanding it will be transformed into expansive power; and this proportion is a function of those two temperatures alone, being represented by

$$\frac{\tau_1 - \tau_0}{\tau_1 - \varkappa},$$

and is independent of the nature of the substance. This principle is known as *Carnot's Law*; and its consequences have also been investigated by Clausius and Professor William Thomson.

The results of these theoretical principles, as applied to the steam-engine, have been developed in practical formulæ and tables, and compared with experiment, and the agreement is in all cases most satisfactory (Trans. Roy. Soc. Edin. vol. xx.).

On the Velocity of Sound in Liquid and Solid Bodies of Limited Dimensions, especially along prismatic masses of liquid. By W. J. M. RANKINE.

This paper is a sequel to one read at Edinburgh to the British Association in August 1850, and published in the Cambridge and Dublin Mathematical Journal for February 1851, on the Laws of Elasticity.

Its immediate object is to determine to what extent our present knowledge of the condition and properties of elastic bodies enables us to use experiments on the velocity of sound in them as data for calculating the elasticity of the materials. If it were possible to ascertain the velocity of propagation of vibratory movements along the axes of elasticity of an indefinitely extended mass of any substance, we could at once calculate the coefficients of elasticity of the substance; for in such a mass we can assign the directions of molecular oscillation corresponding to each direction of propagation, and consequently the nature of the elastic force called into play. Such experiments, however, are possible in air and water only. For other substances, the best data which it is practicable to obtain are experiments on the velocity of sound along prismatic or cylindrical masses.

The author in the first place integrates the equations of small molecular oscillations in elastic bodies of limited dimensions, and of any structure, and afterwards investigates the special results to which they lead in the case of uncrystallized media generally, and of prismatic bodies of liquid in particular. The principal positive conclusions arrived at may be summed up as follows:—

I. In liquid and solid bodies of limited dimensions, the freedom of lateral motion possessed by the particles causes vibrations to be propagated less rapidly than in an unlimited mass.

II. The symbolical expressions for vibrations in limited bodies are distinguished by containing exponential functions of the coordinates as factors; and the retardation referred to depends on the coefficients of the coordinates in the exponents of those functions, which coefficients depend on the molecular condition of the body's surface, a condition as yet imperfectly understood. [Exponential functions in the equations of small oscillations have not hitherto been used, except in the theory of waves propagated by gravitation, by Mr. Green, in that of total reflexion, and by Professor Stokes, in investigating the possible effect of radiation on the velocity of sound.]

In an uncrystallized body in particular, if A represent the coefficient of longitudinal elasticity; that is to say, the quantity by which an elongation or compression, *without lateral yielding*, must be multiplied in order to give the pressure per unit of area to which it corresponds*; if D denote the weight of unity of bulk of the substance, and g the accelerating force of gravity, then, while $\sqrt{\frac{Ag}{D}}$ denotes the velocity of sound in an unlimited expanse of the substance, that in a body of limited dimensions is denoted by $\sqrt{\frac{Ag}{D}\cdot(1-h^2)}$, where h is a quantity depending on the figure and molecular condition of the body's surface, and entering into the exponents of the exponential factors in the equations of motion. The trajectory or orbit of an oscillating particle is, generally speaking, a straight line in an unlimited expanse, and an ellipse in a limited body.

III. If we adopt the hypothetical principle, that *at the free surface of a vibrating mass of liquid the normal pressure depending on the mutual actions of atomic centres only is always null*, then we deduce from theory that the ratio $\sqrt{1-h^2} : 1$ of the velocity of sound along a mass of fluid contained in a rectangular trough to that in an unlimited expanse, is $\sqrt{2} : \sqrt{3}$, that ratio being independent of the specific rigidity of the liquid, provided only that it has some amount, however small. This theoretical conclusion is exactly verified by a comparison of the numerous experiments of M. Wertheim on the velocity of sound in water at various temperatures, from 15° to 60° Centigrade, in solutions of various salts, in alcohol, turpentine and æther (Ann. de Ch. et de Phys. Ser. III. tom. xxiii.), with those of M. Grassi on the compressibility of the same substances (Comptes Rendus, xix. p. 153), and with the experiments of MM. Colladen and Sturm on the velocity of sound in an expanse of water. To these may be added the following negative conclusions:—

IV. We are not warranted in concluding from M. Wertheim's experiments (as he is disposed to do) that liquids possess a momentary rigidity as great as that of

* The quantity A is greater than the modulus of elasticity, because, in computing the latter quantity, the particles are supposed at liberty to yield laterally.

solids; seeing that any amount of rigidity, however small, will account for the phænomena, if we adopt certain suppositions as to molecular forces.

V. Our knowledge of molecular forces is not as yet sufficiently advanced to enable us to use experiments on the velocity of sound as a means of determining accurately the coefficients of elasticity of solids.

If we adopt for them the hypothesis already stated with respect to liquids, a theoretical investigation given in an Appendix shows that the velocity of sound in a cylindrical rod of an uncrystallized substance, whose surface is absolutely free, will be less than that in an unlimited expanse in a ratio which is sensibly $1 : \sqrt{2}$ for a very slender filament, and approaches $\sqrt{2} : \sqrt{3}$ as the diameter of the rod increases; but the absolute freedom of the surface cannot be realized in practice; the means used in fixing the rod tend to restrain the lateral oscillations and accelerate the velocity of sound. The ratios ascertained by experiment range from $\sqrt{2} : \sqrt{3}$ to near equality; but they are not sufficiently numerous to form data for any definite conclusions.

The oscillations treated of in the special problems of the body of the paper being of a kind called *nearly longitudinal*, a second Appendix is added, containing the general equations of another kind, called *nearly transverse*, in uncrystallized bodies.

On a General Theory of Gases. By J. J. Waterston, *Bombay.*

The author deduces the properties of gases, with respect to heat and elasticity, from a peculiar form of the theory which regards heat as consisting in small but rapid motions of the particles of matter. He conceives that the atoms of a gas, being perfectly elastic, are in continual motion in all directions, being restrained within a limited space by their collisions with each other, and with the particles of surrounding bodies. The *vis viva* of those motions in a given portion of gas constitutes the quantity of heat contained in it.

He shows that the result of this state of motion must be to give the gas an elasticity proportional to the mean square of the velocity of the molecular motions, and to the total mass of the atoms contained in unity of bulk; that is to say, to the density of the medium. This elasticity, in a given gas, is the measure of temperature. Equilibrium of pressure and heat between two gases takes place when the number of atoms in unity of volume is equal, and the *vis viva* of each atom equal. Temperature, therefore, in all gases, is proportional to the mass of one atom multiplied by the mean square of the velocity of the molecular motions, being measured from an *absolute zero* 491° below the zero of Fahrenheit's thermometer.

If a gas be compressed, the mechanical power expended in the compression is transferred to the molecules of the gas increasing their *vis viva*; and conversely, when the gas expands, the mechanical power given out during the expansion is obtained at the expense of the *vis-viva* of the atoms. This principle explains the variations of temperature produced by the expansion and condensation of gases—the laws of their specific heat under different circumstances, and of the velocity of sound in them. The fall of temperature found on ascending in the atmosphere, if not disturbed by radiation and other causes, would correspond with the *vis viva* necessary to raise the atoms through the given height.

The author shows that the velocity with which gases diffuse themselves is proportional to that possessed by their atoms according to his hypothesis.

Light, Heat, Electricity, Magnetism.

On the Conduction of Electricity through Water. By F. C. Bakewell.

Mr. Bakewell stated the results of some experiments on the conduction of electricity by water, made with a view to prove that an electric current may be transmitted for a considerable distance through unprotected wires immersed in water. The experiments were conducted on Saturday last in one of the Hampstead ponds. A thin copper wire (No. 20), three hundred and twenty feet long, was stretched across the pond, and two copper plates ten inches square, to which wires were soldered,

were also immersed to serve as conducting plates for the return current. A Smee's battery of two pairs of plates was used, and when the connexion was made with a galvanometer on the opposite bank, a steady deflection of 30° was maintained, and a strong blue mark was produced by a steel electrode on paper moistened with a solution of prussiate of potash in diluted muriatic acid. In this experiment the conducting plates were placed close to the wire, and on opposite sides of it, so that the return current passed diagonally across the exposed wire. The water in this case appeared to act as a conductor and as a non-conductor at the same time, in proportion to the surfaces exposed to its influence. In the next experiment the wire was doubled, and a current of electricity from the same battery was transmitted through the wires, both being immersed in the water. In this case the deflection of the needle was more prompt, and it continued steady at 45°. From these experiments, which Mr. Bakewell stated were a confirmation of those undertaken by Mr. Bain and Lieut. Wright with a different object in 1841, he inferred that the exposure of a large surface, as the electric telegraph wires from post to post, presented greater opportunity for the dispersion of electricity in moist atmospheres, than the points of connexion with the posts, even supposing the wires to be entirely uninsulated and connected by water with the earth.

On a New Mode of Illuminating Opake Objects under the highest powers of the Microscope. By Charles Brooke, *M.B., F.R.S.*

A parallel pencil of rays is obtained by placing a camphine-lamp (which of all kinds of lamps gives the most intense illumination) in the principal focus of a combination of two plano-convex lenses. This pencil is received on the surface of a small parabolic mirror, the vertex of which is truncated, so that the focus of the mirror may be about 0·1 inch beyond the truncated edge. The rays which are converging to the focus are received on the surface of the small plane mirror, which is attached to the bottom of the object-glass, so that the surface of the mirror may be nearly level with the lowest surface of the object-glass. All the rays of light which subtend any angle from that of the object-glass, up to about 170°, are thus rendered available for the illumination of the object, which, as it is illuminated by very oblique rays, must not be placed in a depression or cavity of any kind.

On a New Arrangement for facilitating the Dissection and Drawing of Objects placed under the Microscope. By Charles Brooke, *M.B., F.R.S.*

Two short pieces of tube, one of them the size of the eye-piece, the other the same size as the body of the microscope, are attached at an angle of about 4° to the sides of a brass box containing a rectangular prism. The smaller tube enters the body of the microscope, and the larger receives the eye-piece. The image that enters the eye is now inverted in a plane passing through the axes of the body and of the eye-piece; and in order to erect the image, a cap is placed over the eye-piece, to which is attached a small rectangular prism, having its axis in the plane in which the image is already inverted. This arrangement provides a very convenient position of the eye, when the hands are engaged in manipulating an object placed under the microscope.

A rectangular prism has already been introduced into the body of the microscope by Nachez; but as this was placed near the object-glass, it must to a certain extent interfere with the definition of the object. For the purpose of drawing, a small piece of parallel glass is substituted for the rectangular prism placed in front of the eye-piece, through which the drawing-paper is seen directly through two opposite surfaces, and the object is seen by reflexion from an outer surface placed at an angle of about 45° with the axis of the eye-piece. The image inverted by the first reflexion is again inverted in the same plane by the second, and is therefore correctly represented in the drawing.

On the Progress of Experiments on the Conduction of Heat, undertaken at the Meeting of the British Association at Edinburgh, in 1850. *By* Professor J. D. Forbes, *Sec.R.S.E.*

After the close of the Edinburgh meeting I lost no time in preparing for the pro-

secution of these experiments. I first of all ordered a series of thermometers from Fastré of Paris. I had next to devise a suitable heating apparatus; and finally I had malleable iron bars made, my experiments having as yet been confined to that metal. The mode of conducting the experiments, and of deducing results from them, I shall not now enter upon; because, although the progress of the experiments has perhaps been as great as the difficulties of the inquiry and my very limited leisure entitled me to expect, I think it very desirable to repeat and extend them further before drawing any positive conclusions. I may state, however, that my method has been communicated to Mr. Airy, the President elect of the Association, to Professor Kelland, and to another scientific friend, and I have received every encouragement from these gentlemen to proceed in the inquiry, which will I hope be considered by the General Committee as a proof that these experiments have not been lightly undertaken.

On these grounds I request a renewal of the grant of 50*l.* for the ensuing year, although it is not at all likely that the whole, or even two-thirds of that sum, should be required. Of the 50*l.* granted last year, I have spent only 20*l.* 1*s.* 1*d.*, of which a detailed account has been handed to the General Treasurer. Some smaller expenses are still unpaid. Messrs. Napier, the eminent machine-makers, have generously supplied two admirably made bars, free of all cost.

Letter addressed to Lieut.-Col. Sabine, *R.A.* (*General Secretary*), *by* Captain Edw. J. Johnson, *R.N.*, *F.R.S.*

This communication was made in a letter to Col. Sabine, of which the following extract gives the substance:—

You will perceive by the deviation tables of H.M. ships Ajax and Blenheim*, that if no heed were taken of the deviation when regulating the ship's course, the most serious consequences might be apprehended.

Taking as an example the case of the Ajax, with the funnel *up*, running upon an easterly course at the rate of 9 knots per hour, a simple diagram will show that in 24 hours only, if no allowance were made for deviation, the ship would be 50 miles out of the reckoning; and with the funnel *down*, the error would be increased to 72 miles in the same space of time, while the case of the Blenheim would not be very different.

In the humid and misty atmosphere which so often prevails on the coasts of the British Isles, the fact that a ship such as the Ajax, if steered a compass course (but without allowing for deviation) for mid-channel between Ushant and the Lizard, would instead thereof be running for the dangers about Ushant, with the funnel *up*, and with it *down*, be so far out of the proper course as to be advancing towards the rocks south of Douarnenez Bay, is I conceive a proper example to show the importance of attending to the effects produced upon the compass under the two conditions of the funnels of steam ships.

But besides the practical question, I wish you to bring under the notice of the Section, the following results which I obtained with reference to the effect of hollow iron cylinders upon the compass, when placed inside of each other; the object being to ascertain whether the whole difference of deviation, under the two conditions of these telescopic funnels, was due to the difference of their elevation and depression only, or whether a portion of the said differences was attributable to the induced magnetism of the separate parts of the funnel, when lowered, acting upon each other.

As it would have required more time than could be afforded to hoist the parts of these huge funnels in and out of the ship while the requisite successions of observations were made, I procured three hollow iron cylinders, of smaller dimensions, their several diameters being such as to admit of one cylinder being placed inside of another, and leaving a space of about an eighth of an inch between their surfaces.

Having placed a standard compass on one of the pedestals in the observatory, and ascertained the magnetic meridian for the moment by the collimator, the largest or external iron cylinder, No. 1, was brought in, and placed to the *eastward* of the com-

* These ships mount 58 guns each, and have engines of 450 horse power.

pass, the principal mass of the cylinder being below the level of the needle and card, and its upper end being $2\frac{1}{2}$ inches above that level.

By this means a deflection or deviation of 10° 10′ was produced, the north end of the needle being drawn that amount to the eastward of the correct magnetic north.

Cylinder No. 2 was next placed inside of No. 1, when the deviation was increased to 12° 15′.

Cylinder No. 3 was then placed inside of No. 2, and the deviation was again increased to 14° 15′, the north end of the needle being drawn to the eastward in each case.

Hansteen's magnetic force instrument was then placed with the centre of its needle (as nearly as I could adjust it) in a similar position to that which the centre of the compass had occupied, and the following results were obtained :—

	Time of 100 vibrations, starting from an arc of 18°.
Previous to the cylinders being brought into the observatory	6′ 57″
No. 1 cylinder in place	6 51
No. 2 cylinder in place inside of No. 1	6 47
No. 3 cylinder in place inside of No. 2	6 45

The force instrument being removed, a dipping-needle was then employed, and the following are the results of the observations :—

	Mean of Readings. Dip.
Previous to the cylinders being brought into the observatory	68° 37′
No. 1 cylinder placed to the *south* of the instrument	70 10
No. 2 cylinder in place inside of No. 1	70 27
No. 3 cylinder in place inside of No. 2	70 37

The conclusion to be deduced from all these observations appears to be, that to the induced magnetism of the surfaces of each cylinder, acting upon each other, is due a portion of the deviation; and reasoning by analogy, a similar deduction is applicable to the telescopic funnels of steam ships.

Results of Experiments with three Iron Cylinders, showing their Effect upon the Compass, the Dipping-Needle, and Hansteen's Magnetic Intensity Instrument, when placed in given positions. Observers, Capt. Johnson *and* Mr. Brunton.

		Time of 100 vibrations of Hansteen's Intensity Needle, starting from an arc of 18°. N. 6′ 57″.
Bearing of distant mark before the cylinders were brought into the observatory	N. or 0° 0′	
No. 1, or largest cylinder in place to the eastward of the compass	N. 10° 10′ W.	6′ 51″
No. 2. Cylinder in place inside of No. 1	N. 12 15 W.	6 47
No. 3, or smallest cylinder, in place inside of No. 2	N. 14 15 W.	6 45

the north end of the needle being drawn to the eastward by the cylinders in each case. The main body of the cylinders were below the level of the compass, and their upper ends $2\frac{1}{2}$ inches above the said level.

Dip before cylinders were placed	68° 37′
Dip No. 1, cylinder in place to the south of the needle	70 10
Dip No. 2, cylinder in place	70 27
Dip No. 3, cylinder in place	70 37

	Ft.	in.
Thickness of iron cylinder	0	$0\frac{3}{16}$
Depth of cylinder	1	6
Diameter of external or largest cylinder, No. 1	1	6
Card A of the standard compass — Length of the two outer needles (each)	0	$5\frac{3}{10}$
Card A of the standard compass — Ditto, two centre ditto	0	$7\frac{3}{10}$
Length of the needle in Hansteen's intensity instrument	0	$2\frac{7}{10}$
Length of the dipping-needle	0	$6\frac{1}{20}$

Tables of the Deviations of the Compasses of H.M. Steam Ships Ajax, of 58 *guns, and Blenheim, of* 58 *guns, under the two conditions of their funnels, viz. Up and Down. Observers,* Capt. Johnson, Commander Strange, and Mr. Thompson.

These ships have engines of 450 horse power, and are propelled by the screw. They have what are termed *telescopic funnels,* capable of being lowered when required; the Ajax having two funnels abreast, the Blenheim one funnel.

Ajax.					Blenheim.				
	Funnel up.		*Funnel down.*			Funnel up.		*Funnel down.*	
Direction of ship's head by standard compass.	Deviation of standard compass.	Direction of Deviation.	Deviation of standard compass.	Direction of Deviation.	Direction of ship's head by standard compass.	Deviation of standard compass.	Direction of Deviation.	Deviation of standard compass.	Direction of Deviation.
N.	0° 20′	E.	0° 10′	*W.*	N.	1° 5′	E.	0° 20′	*E.*
N. by E.	1 40	E.	3 20	*E.*	N. by E.	1 55	E.	4 0	*E.*
N.N.E.	6 40	E.	8 20	*E.*	N.N.E.	2 25	E.	8 10	*E.*
N.E. by N.	9 10	E.	10 50	*E.*	N.E. by N.	4 20	E.	10 10	*E.*
N.E.	11 20	E.	13 10	*E.*	N.E.	6 45	E.	12 10	*E.*
N.E. by E.	13 20	E.	16 40	*E.*	N.E. by E.	8 10	E.	14 40	*E.*
E.N.E.	13 10	E.	18 30	*E.*	E.N.E.	8 40	E.	16 10	*E.*
E. by N.	11 30	E.	16 30	*E.*	E. by N.	8 50	E.	16 10	*E.*
E.	11 50	E.	18 0	*E.*	E.	9 0	E.	15 50	*E.*
E. by S.	11 30	E.	16 50	*E.*	E. by S.	8 30	E.	14 30	*E.*
E.S.E.	9 50	E.	15 0	*E.*	E.S.E.	7 40	E.	12 20	*E.*
S.E. by E.	9 0	E.	13 10	*E.*	S.E. by E.	6 28	E.	14 40	*E.*
S.E.	7 30	E.	11 0	*E.*	S.E.	5 5	E.	9 40	*E.*
S.E. by S.	6 10	E.	9 40	*E.*	S.E. by S.	3 40	E.	7 0	*E.*
S.S.E.	5 10	E.	7 10	*E.*	S.S.E.	2 35	E.	5 30	*E.*
S. by E.	4 30	E.	5 50	*E.*	S. by E.	1 0	E.	2 30	*E.*
S.	1 0	E.	2 10	*E.*	S.	0 0	E.	1 30	*E.*
S. by W.	1 0	W.	0 10	*W.*	S. by W.	1 55	W.	0 50	*W.*
S.S.W.	4 0	W.	3 40	*W.*	S.S.W.	3 15	W.	3 30	*W.*
S.W. by S.	4 0	W.	4 30	*W.*	S.W. by S.	4 43	W.	5 0	*W.*
S.W.	5 20	W.	8 40	*W.*	S.W.	6 11	W.	7 0	*W.*
S.W. by W.	8 0	W.	11 50	*W.*	S.W. by W	7 30	W.	9 0	*W.*
W.S.W.	10 50	W.	13 40	*W.*	W.S.W.	9 40	W.	11 30	*W.*
W. by S.	13 20	W.	14 40	*W.*	W. by S.	11 10	W.	13 40	*W.*
W.	10 10	W.	16 40	*W.*	W.	11 20	W.	15 40	*W.*
W. by N.	11 40	W.	14 30	*W.*	W. by N.	11 55	W.	16 30	*W.*
W.N.W.	11 40	W.	16 40	*W.*	W.N.W.	12 45	W.	16 50	*W.*
N.W. by W.	10 0	W.	16 10	*W.*	N.W. by W.	12 5	W.	15 40	*W.*
N.W.	8 0	W.	14 30	*W.*	N.W.	11 0	W.	13 40	*W.*
N.W. by N.	6 10	W.	11 0	*W.*	N.W. by N.	9 0	W.	11 20	*W.*
N.N.W.	4 40	W.	7 10	*W.*	N.N.W.	6 35	W.	8 10	*W.*
N. by W.	2 50	W.	3 50	*W.*	N. by W.	3 5	W.	4 10	*W.*

	Ft.	in.
Height of standard compass above the deck	5·8	0
Distance from funnels	27	0
Height of funnel when up	23	6
Height of funnel when down	4	6
Depth of funnel below deck when down	19	0
Diameter of each funnel	4	0
Thickness of the iron funnels	0	$0\frac{3}{16}$

	Ft.	in.
Height of standard compass above the deck	5	$3\frac{1}{2}$
Distance from funnel	22	0
Height of funnel when up	24	0
Height of funnel when down	8	0
Depth of funnel below deck when down	16	0
Diameter of funnel	6	0
Thickness of iron funnel	0	$0\frac{3}{16}$
Thickness of steam chest	0	$0\frac{5}{16}$

E. J. Johnson,
Capt. R.N., Superintendent of the Compass Department.

Mr. Bakewell read a paper on the Copying Electric Telegraph, and illustrated its action by experiments with the instruments. In the method adopted for transmitting copies of writing, the letters to be transmitted are written on tin-foil with varnish, so as to present a conducting and a non-conducting surface. The foil is placed on the cylinder of the transmitting instrument, and a metal style in connection with a voltaic battery presses on the surface of the cylinder as it revolves. By this means the electric current is continually broken when the style is resting on the varnish; and as the style is made to traverse by an endless screw from one end of the cylinder to the other, it passes necessarily over all the lines of the writing, and about eight times over each line. The receiving instrument is similar to the transmitting one, and on to the cylinder of that instrument paper, moistened with a solution of prussiate of potass in diluted muriatic acid, is placed, the metal style on that instrument being a piece of steel wire. When the electric current from the positive pole of the voltaic battery passes through the steel point to the paper, a blue mark is made by the production of prussian blue, and when the cylinder is in motion the effect is to draw a series of spiral lines on the paper; but as the lines are broken whenever the varnish writing on the transmitting cylinder interposes, the forms of the letters are transferred from one instrument to the other; the writing appearing of a pale colour on a ground of blue lines drawn closely together. To produce this effect it is requisite that both instruments should rotate exactly together, and this synchronous movement is attained by means of an electro-magnet; one instrument being made to regulate the other by retarding its motion at regular intervals. The regulation of the instruments is also facilitated by a guide-line, consisting of a strip of paper placed at right angles to the writing, by which means the person in charge of the receiving instrument can ascertain exactly how much the speed of the two instruments differs, and by the addition or abstraction of weight can bring the gaps, formed by the strip of paper, to fall exactly under each other, which indicates that the two cylinders are revolving at the same rate. It was stated in answer to questions by members present, that two hundred letters per minute might be copied by the instruments exhibited, and that five hundred a minute are attainable. To illustrate the facility which this means of telegraphic communication affords for transmitting secret messages, an apparently blank piece of paper was produced, on which a message had been impressed invisibly before the meeting of the Section, and by brushing it over with a solution of prussiate of potass the writing became instantly legible.

Remarks on Lord Brougham's *Experiments on Light, &c. in the Phil. Trans.* 1850. *Part I. By the* Rev. Professor Powell, *F.R.S. &c.*

The experiments of Lord Brougham "on the properties of light," &c., are regarded by their author as offering new facts at variance with the principle of interference, hitherto so successfully applied to all phænomena of this class. They seem therefore to call for some remarks as to their actual bearing on the question. The experiments all refer to the well-known phænomena of diffraction-fringes formed by the edge of an opake screen; which the author views in connexion with a peculiar theory of *inflecting* and *deflecting* forces; the nature of the effect being chiefly investigated by placing a *second edge at some distance from the first along the ray*, and occasionally a third; which produces changes in the breadth and position of the fringes. In the author's attack on the interference theory (especially in prop. xi.), some misconception of that theory appears to be involved. Though the undulatory theory has been successfully applied to the general subject of these fringes, yet it is well known that the application of the formulas to any but the simplest cases of edges and apertures is defective, owing to the great complexity of the resulting expressions, and the impossibility of integrating them except under very restricted conditions. Thus the integration has not been extended to the action of a second or third edge *at different distances*; this last case being obviously the same as that of an aperture or screen whose plane is *inclined* to the path of the rays. Fresnel, in his justly celebrated memoir (Sur la Diffraction de la Lumière, Mém. de l'Institut, tome v. for 1821, published in 1826, note, p. 452), considers *briefly* this very case, and shows generally that the fringes will not be symmetrical, having a greater extension towards one side; but he does not give any analytical investigation, which would manifestly

be one of considerable complexity. In an attempt to deduce these expressions at length, it has been found that the expressions become extremely complicated, though it seems difficult to say whether they may not still yield to proper treatment: the main question is, whether the expenditure of time and trouble would not be greater than any results likely to be obtained would repay.

The Earl of Rosse said that, having observed in the London Papers that the President of the Association had in his inaugural address conferred upon him the honour of alluding with approbation to the attempts which he had lately made, and with considerable success, to procure plain specula of silver for reflecting telescopes, he thought that perhaps the Section might wish to hear some particulars, and if they could spare a few minutes he would make a short statement on the subject.

It is well known that about one-third of the light which falls upon the great speculum of the Newtonian telescope is lost in the first reflexion, and that nearly one-third of the remainder is lost in the second reflexion. Light being of the greatest importance, especially in the examination of faint objects, in the Herschelian telescope the second reflexion has been dispensed with altogether; and in the Newtonian telescope attempts have been made, by substituting a prism for the flat mirror, in some degree to reduce the amount lost. In the Herschelian telescope the mirror is inclined, so that the light proceeding in a direction parallel to the axis of the tube is reflected to the centre of the eye-glass fixed to the side of the tube; there is thus but one reflexion. A consequence, however, of placing the great mirror obliquely is, that though it may be truly parabolic, yet a pencil of light proceeding from a point in an object will not be reflected to a point as it should be, but will be diffused over a certain space. In a telescope of 3-feet aperture and 27-feet focus, the diameter of that space will be more than $\frac{1}{100}$th of an inch, so that the magnifying power employed cannot be considerable without producing indistinctness. Were it possible to work the surface assigned by theory for oblique reflexion as accurately as the surface of the paraboloid, we should have the light without the indistinctness; but that has not yet been accomplished. Where specula are very large, it has been proposed to place the eye-glass in the axis of the tube, and it has been contended that the light interrupted by the head and shoulders of the observer would be less than the light lost by the second reflexion. This is no doubt true, and various ways have been suggested of placing the observer so that the light interrupted should be a minimum, the temperature of the air in the tube remaining at the same time undisturbed. In such a construction, however, there would be great diffraction, and that appears to me to be an insurmountable objection. The rectangular prism was proposed by Newton as a substitute for the plain speculum; and with a prism of $2\frac{1}{8}$ inches aperture by Mertz, the saving of light is considerable. Mertz informed me that a somewhat larger prism might be made, but that there would be considerable delay: he did not however hold out any hopes of being enabled to make one large enough for our 3-feet speculum. It is evident that as the size of the prism is increased, the amount of light lost in passing through the glass will be greater, and a point will at length be arrived at, sooner or later, according as the glass is more or less transparent, when the light lost in prismatic reflexion will be as great as in reflexion from a speculum of metal. It occurred to me that a small prism might be substituted for a large one by placing it near the focus, and that practically the inconvenience of a small field might be obviated to a certain extent by employing a plain speculum and eye-piece in the ordinary way for general work, to be turned aside by a suitable contrivance when the prism was to be made use of. An eye-piece, of course of an unusual construction, would be required, and it does not seem practicable to make such an eye-piece with two lenses achromatic: the four-glass eye-piece would be so, but some light would be sacrificed. How far the want of achromatism would interfere with real work I have not proceeded far enough to be able to say. Achromatic prismatic refraction has been proposed by Sir David Brewster as a substitute for the plain speculum. It has not, as far as I am aware of, been tried, but the great size of the prism which would be required appears to me to be a serious objection.

Under these circumstances, it is obvious that where there was a reasonable pro-

spect of obtaining a material for the plain speculum more reflective than the alloy of tin and copper, no time nor labour could be misapplied in endeavouring to effect so important an object. It was not until Jamin's 'Mémoire sur la Couleur des Métaux' appeared in the 'Annales de Chimie' for 1848, that I was aware that silver reflected so very much more light than speculum metal. Jamin states that he has abundantly verified Cauchy's formulæ for the laws of metallic polarization; and from these laws, by the aid of certain constants, he has determined the intensity of light reflected by some of the metals. From the table he has given, it appears that while speculum metal reflects about sixty rays out of a hundred, silver reflects ninety. Not from having any doubt of the accuracy of Jamin's deductions, but happening to have the means at hand, I made a few coarse photometric measurements of the relative reflective powers of silver and speculum metal, and the results appeared to coincide sufficiently with the more accurate deductions of Jamin. Not feeling very sanguine as to the practicability of procuring an accurate surface of silver by mechanical means, owing to its softness, I tried the electrotype process in the first instance. The silver was thrown down upon a surface of highly polished speculum metal; but in every case where the speculum metal was thoroughly clean there was strong adhesion, so that separation could not be effected without destroying both surfaces. The means which were employed to guard against adhesion in electrotyping the engraved copper plates for the Ordnance Map of Ireland, which, in fact, consisted in applying an extremely thin film of wax, would obviously be inadmissible in this case. Several attempts to precipitate silver on a steel speculum failed, as the silver had not a proper polish. Being however without experience in electrotyping, I do not consider these failures conclusive. Attempts were made with a steel die truly polished to procure accurate polish by pressure. This did not succeed: the surface was not sufficiently true, owing apparently to unequal elasticity in the texture of the silver. To turn or plane a polished surface was not attempted, as the idea had suggested itself to the late Mr. Barton, and if it had been practicable in his hands it would doubtless have succeeded. There remained therefore but to try some modification of the ordinary processes of polishing metals. A difficulty occurred in the beginning, which gave considerable trouble. Owing to the softness of the silver, the emery employed to grind it flat became imbedded in it, and in that state to polish it was quite impossible. Without grinding, however, there seemed to be no means of making the silver sufficiently flat, as Whitworth's scraping process had been tried, and was not found to be sufficiently delicate. The difficulty was obviated by employing a bed of German hones, by which the silver is probably rather filed than ground. The blue hones might perhaps be employed with advantage after the German hones, but I have not tried them. The silver being thus prepared, I tried the ordinary process of polishing on pitch in vain, employing the pitch of various degrees of hardness: the surface of the silver was irregular and the polish imperfect. The silversmith makes use of chamois leather and rouge, sometimes finishing with the hand charged with rouge: his polish is very brilliant, but the surface is, as we should expect, very untrue, as for example, the surface of a highly finished plateau. It was rather puzzling to find that while chamois leather charged with rouge polished silver, pitch, however soft, did not: there was no apparent difference in the two cases, but this; that the pitch slightly shielded by the rouge came more or less in contact with the silver, while the chamois leather, holding fast the stratum of rouge, was scarcely in contact at all with the silver. That this was the true reason was probable, as in proportion as the chamois leather was less shielded, the process was imperfect. It is evident that, however fine the polish, a true surface could not be procured by the action of an elastic material, and therefore pitch was taken as a basis; a substance which is solid, and at the same time adapts itself in the most perfect manner to the surface to be polished. We proceeded in this way:—Pitch of the proper hardness for polishing speculum metal was covered with a mixture of rouge and the combination of ammonia and soap which we employ in polishing specula. The silver was worked upon this for a short time to force the rouge into the pitch, after which the rouge mixture was again applied and suffered to dry. The surface was then slightly moistened with spirits of turpentine, and more of the rouge mixture applied. The following day, the turpentine having evaporated, there was a rouge surface, perhaps of $\frac{1}{100}$th of an inch thickness,

upon which the silver was polished, using fresh rouge and ammonia soap just as if it was speculum metal. The spirit of turpentine had long been exposed to the light, and consequently was slightly adhesive. Silver was several times polished on this surface successfully, and a plain silver speculum so polished performed well, giving perfectly sharp images. I have been thus minute in explaining what I believe to be the rationale of the process as a guide to others, because, having as yet practised it but little, I may perhaps have omitted to notice some things apparently non-essential, but which are really not so.

On a new Elliptic Analyser. By Prof. G. G. Stokes, *M.A., F.R.S.*

After alluding to various methods which had been employed in investigating experimentally the nature of elliptically-polarized light, that is to say, the elements of the ellipse described, the author exhibited and described a new instrument which he had invented for the purpose. In its construction he had aimed at being in all important points independent of the instrument-maker, assuming nothing but the accuracy of the graduation.

The construction is as follows:—A brass rim, or thick annulus, is fixed on a stand, so as to have its plane vertical. A brass circle, graduated to degrees, turns round within the annulus, and the angle through which it is turned is read by verniers engraved on the face of the annulus. The brass circle is pierced at its centre, and carries on the side turned towards the incident light a plate of selenite, of such a thickness as to produce a difference of retardation in the oppositely polarized pencils amounting to about a quarter of an undulation for rays of mean refrangibility. On the side next the eye the brass circle carries a projecting collar, and round this collar there turns a moveable collar carrying verniers, and destined to receive a Nicol's prism.

The observation consists in extinguishing the light by a combination of the two movements. The retarding plate converts the elliptically-polarized light which has to be examined into plane-polarized, and this plane-polarized light is extinguished by the Nicol's prism. There are two distinct positions of the retarding plate and the Nicol's prism in which this takes place. In each of these principal positions the retarding plate and the Nicol's prism may be reversed (*i. e.* turned through 180°), and the means of the readings in these four subsidiary positions may be taken for greater accuracy. The readings of the fixed and moveable verniers in each of the two principal positions are four quantities given by observation, which determine four unknown quantities, namely, (1) the index error of the fixed verniers, or, which comes to the same, the azimuth of the major axis of the ellipse described by the particles of æther, measured from a plane fixed in the graduated circle; (2) the ratio of the axes of the ellipse; (3) the index error of the moveable verniers; (4) the retardation due to the retarding plate. The unknown are determined by the known quantities by certain simple formulæ given by the author.

Let these unknown quantities be denoted by I, tan ϖ, i, and ϱ, respectively, the latter being reckoned as an angle, at the rate of 360° to an undulation. Let R, r be the readings of the fixed and moveable verniers respectively in one of the principal positions, R′, r' the corresponding readings in the other; then

$$\mathrm{I}=\frac{\mathrm{R}'+\mathrm{R}}{2}; \quad i=\frac{r'+r}{2};$$

$$\cos 2\varpi=\frac{\sin(r'-r)}{\sin(\mathrm{R}'-\mathrm{R})}; \quad \cos\varrho=\frac{\tan(r'-r)}{\tan(\mathrm{R}'-\mathrm{R})}.$$

The author stated that he had made a good many observations with this instrument for the sake of testing its performance, and that he had found it very satisfactory. Inasmuch as light is not homogeneous, the illumination never vanishes, but only passes through a minimum, and in passing through the minimum the tint changes rapidly. This change of tint is at first somewhat perplexing; but after a little practice, the observer is able to point mainly by intensity, taking notice of the tint as an additional check against errors of observation. The accuracy of the observations is a little increased by the use of certain rather pale-coloured glasses.

To give an idea of the degree of accuracy of which the instrument is susceptible, suppose the ratio of the axes of the ellipse described to be about 3 to 1. In this case the author found that the mean error of single observations amounted to about a quarter or the fifth part of a degree in the determination of the azimuth, three or four thousandths in the determination of the ratio of the minor to the major axis, and about the thousandth part of an undulation in the determination of the retardation.

On account of the accuracy with which the retardation is determined, and the largeness of the chromatic variations to which it is subject, the instrument may be considered as determining, not only the elements of the ellipse described, but also the refrangibility of the light employed, or its length of wave, which corresponds to the refrangibility. The author stated that the error of the thousandth part of an undulation, to which the determination of the retardation was subject, corresponded to an error of only the twentieth or thirtieth part of the interval between the fixed lines D and E of Fraunhofer.

On Diamagnetism and Magnecrystallic Action. By JOHN TYNDALL, *Ph.D.*

One of the most important inquiries which at the present day occupies the attention of the student of physical science, is the relation which subsists between magnetism and diamagnetism. Are the laws which govern both forces identical? Will the mathematical expression of the attraction in the one case be converted into that of the repulsion in the other case by a change of sign from positive to negative?

To this question, M. Plücker replies "No." His experiments have led him to the conclusion, that where the power of a magnet which operates upon a body composed of magnetic and diamagnetic constituents is increased, the diamagnetism of the compound mass increases in a much quicker ratio than the magnetism; that in consequence of this, an indifferent body is a physical impossibility; for a body in which the respective forces might be exactly equal and opposite, when excited by a magnet of a certain strength, would, upon lowering the power of the magnet below this standard, be attracted, and by increasing the power of the magnet beyond this standard be repelled.

During a previous investigation, the author of the present memoir had repeated opportunities of observing phænomena exactly similar to some of those which form the premises of Plücker's conclusion, and a close study of the subject convinced him, that, to account for these phænomena, the hypothesis of two conflicting forces in the same compound mass, the one or the other of which predominates according as the power of the magnet is increased or diminished, was by no means necessary.

To fit himself for the investigation of this question, he commenced an inquiry last November into electro-magnetic attractions; one of the results of this inquiry was, that a sphere of soft iron separated from the end of a straight electro-magnet by a small fixed distance, was attracted by the latter with a force exactly proportional to the square of the exciting current. Now this attraction is in each case the product of two factors, one of which expresses the magnetism of the magnet, and the other the magnetism of the ball, and it is easy to see that while the attraction increases as the square of the current, the magnetism of the ball increases in the simple ratio of the current itself.

Our way to a comparison of magnetic attraction and diamagnetic repulsion is now clear. We know the law according to which the magnetism of an iron ball increases, and we have only to inquire whether the diamagnetism of a bismuth ball follows the same law. The apparatus used in the former case proved, however, to be totally unfit for the measurement of diamagnetic force,—the feebleness of the latter rendered a much more delicate mode of measurement necessary.

The torsion balance was the instrument finally resorted to by the author. A loop of paper was attached to one end of a fine silver wire, and in the loop rested a little beam of light wood. At the ends of the beam, which was 6 inches long, two spoon-shaped hollows were worked out, in each of which a ball of the substance to be experimented with might be placed. Two cores of soft iron, surrounded by helices of copper wire, were placed at right angles to the beam when horizontally suspended, the one core facing the ball at one end, and the other core facing the ball at the

other end. The silver wire was carried upward through a tube three feet in length, and was connected at the top with a torsion head. When the cores were excited, by sending an electric current through the surrounding helices, the balls were repelled. The index of the torsion head was then gently turned against the repulsion until the balls were brought within $\frac{1}{12}$th of an inch of the ends of the respective cores. The torsion necessary to effect this, is evidently the expression of the repulsive force exerted at this particular distance.

The strength of the exciting current was measured by a galvanometer of tangents, and it was regulated by means of a rheostat. The cores were excited by currents which varied from 10° to 57°, and the corresponding repulsions were determined. Spheres of the following diamagnetic substances were used:—1, bismuth of commerce; 2, chemically pure bismuth, obtained by dissolving the material of commerce in nitric acid, precipitating it with distilled water, washing the precipitate for six days successively, and reducing it by means of black flux; 3, sulphur of commerce; 4, spheres from a crystal of native sulphur obtained in Sicily; 5, calcareous spar from Clitheroe; 6, calcareous spar from Andreasberg in the Harz mountains. The diamagnetism of all these spheres followed precisely the same law as the magnetism of the sphere of soft iron; it was exactly proportional to the exciting current.

These results cannot be reconciled with the statement that diamagnetism increases with the increasing power of the magnet in a much quicker ratio than magnetism. The experiments of Plücker might be accounted for in many ways, but such explanations being necessarily conjectural may be omitted here.

It is known that crystalline bodies, suspended between the poles of a magnet, exhibit phænomena which are absent in the case of amorphous bodies. A certain line through the crystal will take up a determinate position, and if the line be forcibly moved away from this position, when the force is removed it will return to it. Thus a crystal of pure carbonate of lime suspended by a silk fibre between the poles with its optic axis horizontal, will always turn until the optic axis is perpendicular to the line joining the poles, in which position it will come to rest. This fact was discovered by Plücker, who referred it to the operation of a new force, which was entirely independent of the magnetism or diamagnetism of the mass of the crystal.

In an investigation conducted by the author, in companionship with Prof. Knoblauch of Marburg, this hypothesis of a new force is rejected, and it is there shown that the position of the optic axis, so far from being independent of the magnetism and diamagnetism of the mass, is entirely changed if a magnetic constituent be substituted for a diamagnetic. Thus, for instance, carbonate of iron differs from carbonate of lime only in the circumstance, that an atom of iron is substituted for an atom of calcium. The crystalline form in both cases is identical, the optic axis of carbonate of iron sets, nevertheless, from pole to pole, with an energy far surpassing that with which the optic axis of carbonate of lime sets perpendicular to the line joining the poles.

But why is it that one direction in the crystal takes up a particular position? The torsion balance gives a prompt answer to this question. A sphere of calcareous spar was placed upon each of the spoon-shaped hollows of the beam, the direction of the optic axis through each sphere being carefully marked. The spheres were first placed so that the optic axes were parallel to the axes of the soft iron cores, and, secondly, perpendicular to the same; the repulsion in the former case was to the repulsion in the latter in the ratio of 53 to 48.

If a bismuth crystal be suspended between two poles, the plane of most eminent cleavage will always set perpendicular to the line joining the poles, that is, equatorial. A cube formed from this crystal was placed on each end of the little beam; first, so that the planes of principal cleavage were parallel to the axes of the cores, and secondly, perpendicular to them:—the repulsion in the former case was to the repulsion in the latter in the ratio of 53 to 38.

The diamagnetic mass in both these cases is repelled with a greater force in one direction than in any other direction. When the crystal is suspended between two poles, the line which marks the direction of maximum repulsion recedes as far as possible from the poles, and hence sets equatorial.

A result, the exact antithesis of the above, was observed with magnetic crystals.

A cube of sulphate of iron was attracted in one direction by a force of 43, and in another direction by a force of 36·3. A sphere of carbonate of iron was attracted in the direction of the optic axis by a force of 43, and in a direction perpendicular thereto by a force of 30·5. When these crystals are suspended between two poles, these lines of chief attraction approach the poles, and finally set axial.

Thus we see that the phænomena exhibited by crystals in the magnetic field, are to be referred to a modification of magnetism or diamagnetism depending, no doubt, upon the peculiar structure of the crystal. Let us endeavour to penetrate this mystery of structure. Our next inquiry is, What direction is that which is chosen by the respective forces for the manifestation of their greatest energy? To this question the author imagines that the following reply is returned by experiment: "If the arrangement of the component particles of any body be such as to present different degrees of proximity in different directions, then the line of closest proximity, other circumstances being equal, will be that of strongest attraction in magnetic bodies, and of strongest repulsion in diamagnetic bodies."

The torsion balance furnishes us with the means of submitting this conclusion to a direct test. A quantity of bismuth was ground to dust in an agate mortar, gum-water was added, and the mass was kneaded into a stiff paste. This was placed between two glasses and pressed together. From the mass, when dried, two cubes were taken, the line of compression being perpendicular to two of the faces of each cube, and parallel to the other four. Suspended by a silk fibre in the magnetic field, upon closing the circuit the line of compression turned strongly into the equatorial position, exactly as the plane of most eminent cleavage in the case of the crystal. The cubes were placed one upon each end of the torsion balance, first, with the line of compression parallel to the axis of the cores, and secondly, perpendicular thereto; the repulsion in the former case was to the repulsion in the latter in the ratio of 53 to 30. A greater differential action was thus exhibited in the case of the model than in the case of the crystal.

A pair of cubes constructed in the same manner from powdered carbonate of iron exhibited an analogous predominance of *attraction* in the line of compression.

Against this mode of experiment an objection was urged, during the meeting of the British Association at Edinburgh last year, by Prof. W. Thomson of Glasgow. "You have," he said, "reduced the mass to powder, but you have not thereby destroyed the crystalline form; your powder is a collection of smaller crystals, and the pressing of the mass together gives rise to a predominance of axes in a certain direction, so that the repulsion and attraction of the line of compression, which you refer to closeness of aggregation, is after all a product of crystalline action. Besides, we know that compressed isinglass exhibits the same optical phænomena as crystals, and you are unable to prove that the action is not due to a quasi-crystalline structure induced in the gum by compression."

The following experiment will set this point at rest. It will not only show the influence of compression apart from the mere arrangement of the axes or from the influence of the gum, for none will be used; but it will also demonstrate the nullity of this presumed axial force when opposed to the influence of compression. To this experiment the author was conducted by the following accident.

The investigation was conducted in Berlin, and the great electro-magnet of the university was beside him at the time. Some notion of the power of this magnet may be gathered from the fact, that the copper helices alone surrounding the iron pillars, which composed the magnet, weighed 243 pounds. On the top of the pillars, two moveable masses of soft iron were placed, each weighing about 25 pounds, and between these the substance to be examined was suspended. A fine cube of bismuth crystal was suspended on one occasion between these moveable poles, and on closing the circuit the planes of most eminent cleavage receded to the equator. Scarcely, however, was this attained when the poles were observed moving towards each other, and, before the circuit could be broken, they had rushed together and clenched their iron jaws upon the crystal. The latter was reduced by the pressure to about three-fourths of its primitive thickness, and immediately suggested the thought, that if the theory of proximity were true it ought to tell here. The pressure brought the particles of the crystal in the line of compression more closely together, and hence a modification, if not an entire reversion, of the former action might be anticipated.

Having liberated the crystal it was boiled in hydrochloric acid, so as to remove any impurity it might have contracted by contact with the iron. It was again suspended between the poles and completely verified the foregoing anticipation. The line of compression, that is, the magnecrystallic axis of the crystal, which formerly set from pole to pole, set now equatorial. The experiment was then repeated with a common vice; various pieces of bismuth, protected by plates of copper, were placed within its jaws, and pressed to the thickness of a shilling. The plates thus obtained, when suspended from their edges in the magnetic field, exhibited one unvarying result: the line of compression stood always equatorial, and it was a matter of perfect indifference whether this line was the magnecrystallic axis or not. In these cases no gum was used, and not only was a 'predominance' of axes present, but they all worked together; they were further assisted by the great mechanical advantage offered by such plates to diamagnetic repulsion; the line of compression, nevertheless, triumphed over all and determined the position of the crystal.

The author concludes his paper as follows :—

"Whoever denies the influence of proximity will have to answer the following questions:—How is it possible that a greater differential action can be exhibited by a cube of bismuth dough than by the crystal itself? What is it which causes the magnecrystallic axis to forsake its usual position, and to set equatorial when the crystal is compressed in the direction of that axis? He must further assume a crystalline structure on the part of wax, flour, shale, and the pith of fresh rolls; for in all these substances the line of compression determines the position of the mass in the magnetic field."

Dr. Tyndall introduced an experiment in thermo-electricity with the monothermic pile recently invented by Prof. Magnus of Berlin. It is well known if two small bars, one of bismuth and the other of antimony, be united at their ends, the other ends being connected by a wire, that on heating the place of contact of the bars an electric current is evoked, which passes from antimony through the connecting wire to bismuth, and from bismuth across the place of contact to antimony. These two metals are mentioned because the phænomenon is exhibited by them with peculiar energy; but any two metals will answer the purpose; and even the same metal, under certain circumstances. Thus Becquerel found that by knotting a wire, and heating it in the vicinity of the knot, a current was developed; it has even been thought that a difference of diameter was sufficient to produce the effect, while some have attributed it to a difference in the radiative power of the metals employed. M. Magnus has been unable to substantiate these views. On taking a wire three lines thick, and reducing a portion of it to the thickness of half a line, when the point of junction of thick and thin was heated, no current was produced; and on taking a length of polished wire, and roughening one half of it with a file or with coarse sand-paper, when the point of junction of rough and smooth was heated, there was no current, although the radiative powers of both portions were very different. With a knot upon the wire no current was obtained up to a temperature of 212° Fahrenheit. It was necessary to heat the wire to redness, and by this means alter its molecular structure before a current could be obtained. The principle of the monothermic pile depends on this molecular change brought about by heating. A length of hard brass wire was taken and heated to redness in alternate lengths of 6 inches; these portions became permanently soft, while the intervening portions remained hard. The wire was coiled round a little wooden frame, and was of the shape of a rectangle. One of the sides of this rectangle was composed entirely of soft wire, and the side opposite of hard wire, while the centres of the remaining two sides were the junctions of hard and soft. When the hard side of the wire rectangle was heated there was no current, and this was also the case when the soft side was heated. But when the junction of hard and soft was taken between the finger and thumb, the mere heat of the hand was sufficient to cause a deflection of 50° by the needle of a galvanometer. The investigation goes to prove that to the production of a thermo-current the contact of different metals is virtually necessary, and that if the same metal exhibit the phænomenon it is because its various parts are in different states of molecular aggregation.

Extract from a Letter addressed to Professor Phillips.
By the Rev. Professor WALKER, *M.A., F.R.S.*

"Wadham College, Oxford,
July 2, 1851.

"My dear Sir,—You will probably have in Section A. some remarks on the pendulum experiment of Foucault. It may be interesting to the Section to know that we have tried it at Oxford, in the Radcliffe Library, and with most satisfactory results. We have observed one point in the motion which may be worth recording, and I have not seen this noticed in other experiments; and it is this, that whenever the plane of vibration approaches the magnetic meridian, the apparent motion of the plane is accelerated, while it is proportionally retarded as it approaches the line which is at right angles to the magnetic meridian. We have observed these effects for more than three weeks. The acceleration in approaching the magnetic meridian is nearly one degree per hour. I had hoped to have been able to present these results in an accurate form, but I have not had time.

"Our pendulum was at first an iron ball with a pointer underneath, weighing nearly 12 pounds, and suspended by a piano wire; the length from point of suspension to bottom is as nearly as may be 80 feet 6 inches. The time of one vibration is a little short of five seconds, more accurately 4·96 seconds. As some thought the iron ball more susceptible of magnetic influence, it was about ten days ago replaced by a lead one of the same weight with a brass pointer. The results, however (as I did not doubt), are just the same as with the iron one.

"I may mention that the observed periodic time of rotation in our experiments does not differ more than a few minutes from that given by the formula $\frac{24}{\text{sine of latitude.}}$ In one instance it came within one minute of theory-*truth*.

"Believe me, my dear Sir, very faithfully yours,
"ROBERT WALKER."

Note.—The conclusions in this letter are drawn from first and somewhat inaccurate observations. The Radcliffe Library is a public room and was visited by numbers during the progress of the experiments. It is intended, during the quiet and leisure of the long vacation, to repeat the observations with more care, and to try also a copper ball and a copper wire.

Inquiries into some Physical Properties of the Solid and Liquid Constituent Parts of Plants. By Professor E. WARTMANN *of Geneva.*

Plants are furnished with different membranes, many of which can be obtained separately. Such are the epidermis of leaves, stems, fruits, &c. These membranes seem to belong to two classes. The first consists of those which are composed of round cells. The second comprises the cuticles in which the elongated cells prevail. When viewed in a polarizing apparatus (such as that devised by Prof. Norrenberg), the latter depolarize light. The action is very striking with the epidermis of *Eucomis punctata,* and a plate of rock crystal with two inverted rotations. A similar action is found when a ray of polarized heat is transmitted through the membrane. If these organs have been steeped for a considerable time in acids or water, they are not deprived of these properties.

The double-refracting power of those tissues is easily perceived by looking through them at a distant window. There are two positions at right angles in which one set only of the cross-bars is seen. The horizontal bars appear when the longer side of the cells is vertical, and *vice versâ.* In intermediate positions, two faintly-coloured images of each are sometimes visible.

If such a thin membrane is interposed between the eye and the flame of a candle, spectra of interference are produced on both sides of the flame, in a direction parallel to the greater length of the cells. The appearance is like that which Fraunhofer has discovered in the network.

Such a structure in the outer coating of a great many plants may, perhaps, not be without some connexion with the ever-changing direction of the plane of polarization of the atmospheric light and heat derived from the sun.

The liquid parts of vegetables are in electrical relations to each other, which may

be readily detected by clear platina wires connected with a very sensible galvanometer. Two have been employed, one of 4000 coils, the other of 20,000. The following results have been arrived at by examination of what happens in different sections or the same section of the plant. Since my investigations, some of these results have been confirmed by M. Becquerel in an independent way.

Electric currents exist in *all* parts of vegetables, except in those which are furnished with insulating substances, or which contain scarcely any internal humidity.

These currents exist night and day, in the sunshine as well as in the shade; they are not destroyed by an exposure to the vapours of æther continued for twenty-four hours, nor by the partial or total separation of the portion examined from the remainder of the plant, so long as that portion is not dry.

In the roots, the stems, the branches, the petioles and the peduncles, a central descending current and a peripherical ascending one are to be found, which may be called *axial* currents.

On connecting, by means of the galvanometer, the layers of the stem where the liber and the alburnum touch (and where several botanists admit a descending flow of elaborated sap), either with the more central parts, such as pith and perfect wood, or with the younger bark, a lateral current appears from these layers to the neighbouring organs.

The strength of these currents, as well as of those which are exhibited in the other parts of the plant, depends on the energy of vegetation and the abundance of sap pervading the part under examination.

A current is also found when any portion of the plant is placed in the circuit of the galvanometer, the other extremity of the wire being inserted in the soil at a distance which may be very considerable if the tract is wet. The plant is negative in relation to the soil.

All these phænomena (the connexion of which with those described by MM. Matteucci and Dubois-Reymond is obvious) may probably be explained by the fact, that when two portions of a liquid, acid, alkaline or neutral, the concentration of which is different, are separated by a porous organic membrane, a current of electricity proceeds from the denser to the rarer.

The electric state of the soil, and perhaps the exhalation which takes place in the organs furnished with stomata, have an influence upon the electricity of the ambient atmospheric strata.

Description of a Sliding Rule for converting the observed Readings of the Horizontal and Vertical Force Magnetometers into Variations of Magnetic Dip and Total Force. By JOHN WELSH, *Kew Observatory.*

The formulæ for converting the observed changes of the two components of magnetic force into their resultants, dip and total force, are

$$\text{arc}^{-1}\Delta\theta=\frac{\frac{1}{2}\sin 2\theta}{0{\cdot}0002909}\left(\frac{\Delta Y}{Y}-\frac{\Delta X}{X}\right) \text{ and } \frac{\Delta R}{R}=\sin^2\theta\,\frac{\Delta Y}{Y}+\cos^2\theta\,\frac{\Delta X}{X};$$

where θ=magnetic dip; R, the total magnetic force; X, the horizontal, and Y, the vertical components of force.

The formula for changes of dip therefore is of the form

$$\text{Angular change of dip}=a\text{V}-b\text{H},$$

where V and H are the observed scale readings of the vertical and horizontal force instruments, and a and b certain factors depending upon the dip at the place, and the scale coefficients of the instruments employed.

In Plate I, fig. 2, let A be a fixed scale representing the variation of dip in angular measure; let e be the adopted length for one minute on the dip scale A; then make a scale B on one edge of the sliding piece, such that one of its divisions $=\frac{e}{a}$. Similarly, on the other edge make a scale C, one of whose divisions $=\frac{e}{b}$. These scales must be so placed that when the slide is closed the zero points of all shall be in a line. Draw also a fixed mark m, in such a position, that when the slide is closed it shall point to the upper extremity of the horizontal force scale C.

Let the numbers of the scale divisions increase in the same direction in all the scales.

The formula for changes of total force is of the form

$$\text{Variation in parts of total force} = c\text{V} + d\text{H}.$$

Let D be a fixed scale representing the variations of total force; f the length of unit of scale adopted. Make on the edge of the second sliding piece a scale E, such that one division $= \frac{f}{c}$. Make a fixed scale F on the other side of the sliding-piece, whose division $= \frac{f}{d}$. Place the scales so that when the slide is closed the zero-points shall be in a line. Draw also an index n on the sliding-piece, corresponding to zero on scale E, and let the numbers of the scales increase in the same direction as before.

To use the instrument:—1st. Move the first slide until the mark m is opposite to the scale reading of the horizontal force on C; find on B the scale reading of the vertical force, and opposite to it on A is the number representing the variation of dip from an assumed zero. 2nd. Move the second slide until the index n points to the horizontal force reading on F; then on D, opposite to the vertical force scale reading on E, is the variation of the total force in parts of the whole force.

Astronomy, Meteors, Waves.

Account of the Astronomical Instruments in the Great Exhibition. By Dr. Bateman.

Description of an Apparatus for making Astronomical Observations by means of Electro-Magnetism. By G. P. *and* R. F. Bond, *of the Cambridge United States Observatory.*

The apparatus exhibited to the Section is the same which has been in use at the Harvard Observatory, Cambridge, U.S., and is the property of the United States Coast Survey. It consists of an electric break-circuit clock, a galvanic battery of a single Grove's cup, and the spring governor, by which uniform motion is given to the paper. Two wires pass from the clock, one direct to the battery, and the other through the break-circuit key used by the observer, and through the recording magnet back to the battery. The length of the wire is of course immaterial. When the battery is in connection, the circuit is broken by the pallet leaving the tooth of the wheel, and is restored at the instant of the beat of the clock, which is in fact the sound produced by the completion of the contact restoring the circuit, the passage of the current being through the pallet and the escapement-wheel alone. With the exception of the connecting wires, and the insulation of some parts, the clock is like those in common use for astronomical purposes.

Several forms have been proposed by different persons for interrupting, mechanically, the galvanic circuit at intervals precisely equal. In the present instance the clock is of the form proposed by Mr. Bond. Prof. Wheatstone, Prof. Mitchell, Dr. Locke, Mr. Saxton and others, have contrived different modes of effecting this object; the former several years since, but for a purpose distinct from the present.

The cylinder makes a single rotation in a minute; the second marks, and the observations succeed each other in a continuous spiral. When a sheet is filled, and it is taken from the cylinder, the second marks, and observations appear in parallel columns, as in a table of double entry, the minutes and seconds being the two arguments at the head and side of the sheet.

The observer with the break-circuit key in his hand or at his side, at the instant of the transit of a star over the wire of a telescope, touches the key with his finger. The record is made at the same instant on the paper, which may be at any distance, many hundred miles, if required, from the observer. It is a well-established fact, that not only may observations be increased in number by this process, but that the limits of error of each individual result are also narrowed. As far as comparisons

have yet been made, the *personal* equation between different observers, if not entirely insensible, is at least confined to a few hundredths of a second.

It is through the facilities and means furnished by the Coast Survey Department of the United States, under the superintendence of Dr. A. D. Bache, that individuals there have been enabled to bring to its present stage the application of electro-magnetism to the purposes of geodesy and of astronomy; it having been at the expense of that department, and frequently by its officers, that nearly all the experiments have been conducted.

Daguerreotypes of the moon were shown to the Members of the Section, taken by Messrs. Whipple and Jones of Boston, from the image formed in the focus of the great Equatorial of the Cambridge United States Observatory.

On a Method of Sounding in Deep Seas. By J. P. Joule, *F.R.S.*

The impossibility of sounding the depth of the ocean by the ordinary plumb-line has been remarked for nearly three centuries, and during that time numerous inventions have been made in order to measure great depths at sea. The instrument which appeared most feasible consisted of two bodies, which in connexion with one another, sank to the bottom, where, becoming detached, the body of lighter specific gravity rose to the surface. The time occupied indicated the depth of the water, which was otherwise ascertained by vanes propelled by the water during the motion of the sounding apparatus through it.

In these instruments, the body which was intended to float to the surface was generally of wood. But, beyond a very limited depth, an instrument composed of such a material would fail to give any result; for Scoresby has shown that when wood is sunk in a deep sea, it becomes so saturated with water as to become of greater specific gravity than that fluid. To overcome this difficulty, the wood has been covered with pitch, &c.; but it may be doubted whether such a coating would prevent the penetration of water under great pressure. I find, moreover, that light wood, cork, &c., when subjected to a pressure of some tons on the square inch, are crushed so as to become specifically heavier than water; and that they remain so even after the pressure has been removed. A wooden float would therefore be crushed, even if the coating of pitch were sufficient to keep out the water from its pores.

A method of overcoming this difficulty has been recently devised by M. Faye, in which he substitutes a vessel of sheet-steel filled with oil, or other light inelastic fluid, for the wooden float. M. Faye recommends the use of a cylinder of sheet-steel 1 metre high, and 2 decimetres in diameter, which, filled with potato oil, would have a specific gravity of 0·88 in comparison with sea-water, and a force of ascension equal to 15 kilogrammes. For further details of his apparatus, see the 'Comptes Rendus,' January 20.

I believe it to be impossible to improve upon the general principle adopted by M. Faye, but it has occurred to me that a great improvement in the detail would be effected by substituting for the metallic vessel in his apparatus, one of gutta percha, which if filled with alcohol or a light oil, need not exceed the gravity of 0·8, that of sea-water being called unity. In this case the ascending force would be nearly double that of M. Faye's instrument. As a further means of increasing the velocity of ascension, the gutta percha vessel should be constructed on Mr. Russell's wave principle. If the float were 10 feet long, and 1 foot in its greatest diameter, and furnished with a proper weight, a depth of 7 miles might be sounded in less than one hour.

Dr. Faraday submitted, on the part of Dr. Roxburgh, a specimen of dark glass to the examination of the Section under the following circumstances:—

It had been employed to darken the image of the sun outside the eye-piece of a telescope of 3 inches aperture and 47 inches focal length; the magnifying power of the eye-piece was 100, and the dark glass was placed at the distance of about one-eighth of an inch from it. No other eye-piece produced the same effect. In about two minutes after the telescope had been directed to the sun, and the focus adjusted, the greater part of the field of view became dim, as if the glass had been breathed on, and the definition became suddenly destroyed. When the glass was examined

under high magnifying power, a minute portion on the surface next the telescope was found to have been completely melted, a small pimple surrounded by a hollow having been formed. Six or seven dark glasses have been destroyed in the same way; not one has been broken, all having had the small portion of the surface melted. Latterly this accident has been prevented from recurring by placing the dark glass closer to the telescope.

On M. Guyot's *Experiment. By the* Rev. Professor Powell, *F.R.S. &c.*

The recent experiment of M. Foucault, giving direct proof of the earth's rotation, having excited so much attention, it seems remarkable that an equally striking one devised and tried by M. J. Guyot in 1836, should have been passed over or forgotten. That gentleman conceived, that as a falling body deviates to the east, a long plumb-line ought to do the same. This experiment he performed in the dome of the Pantheon at Paris, with a plumb-line about 172 feet long, and determined the deviation to be $4\frac{1}{3}$ millims. in 57 metres. His mode of experimenting was by small balls, one at the point of suspension, the other at the weight, whose images, strongly illuminated and reflected in a basin of mercury placed below, were viewed from above and found to coincide, when the eye was laterally distant $4\frac{1}{3}$ millims. from the upper ball. The experiment might probably be simplified without the trouble of illumination, by making the suspension from a pin passed across a small circular aperture in a flat roof, the light coming through, which would probably give a sufficiently light image in the mercury below. The effect is also stated to be sufficiently *perceptible* with much less length. But much doubt has been expressed with respect to the *principle*. It seems, therefore, desirable that attention should be drawn to the question.

Communication respecting the Comet of Short Period discovered by Brorsen, *February* 26, 1846, *and its reappearance in* 1851. *By* Dr. Von Galen.

Of the different heavenly bodies which made their appearance in the year 1846, the comet discovered by Brorsen, February 26, merits our special attention, on account of its short period of revolution round the sun.

From fifty-five of the best observations made on this comet, in which are included the two observations made at the Greenwich observatory, I have determined the following fundamental positions.

Mean time, Greenwich. 1846.	Comet's right Ascension.	Comet's Declination.
	° ′ ″	° ′ ″
Feb. 33·924600	12 54 36·40	N. 26 33 1·05
„ 44·029902	8 26 43·33	43 30 48·14
„ 50·990194	1 44 47·14	54 28 51·06
„ 57·495320	351 12 52·81	63 25 33·63
„ 80·976101	260 5 27·57	71 2 29·00

and hence by the method of least squares found the most probable elements to be:

Perihelion passage, 1846, Feb. 25·423919, mean time Greenwich.

	°	′	″	
Longitude of the perihelion, π	116	28	37·71	Mean deg. Feb. 26.
„ „ ascending node, Ω ..	102	34	12·92	
Inclination of orbit, ι	31	1	1·86	
Angle of excentricity, ϕ	52	46	13·57	
Mean daily sidereal motion, μ	0	0	623·0164	
Log. semiaxis majoris, Log. a	0	0	0·5036714	
Motion	Direct.			

Taking departure from these elements, I ascertained the perturbations produced by the principal planets of the solar system on the comet, and with regard to these perturbations, got the following system of elliptical elements for its next appearance:

Perihelion passage, 1851, Nov. 10·3377, mean time Greenwich.

	°	′	″
Longitude of the perihelion	116	34	2·61
,, ,, ascending node..............	102	35	46·10
Inclination of orbit	30	58	35·86
Angle of excentricity	52	44	26·57
Mean daily sidereal motion	0	0	621·7965
Log. semiax. maj.	0	0	0·5042389
Motion..	Direct.		

By these elements I have calculated a daily ephemeris, beginning at the 7th Sept. 1851, and ending January 12, 1852, from which ephemeris the following is an extract.

Date.	Mean time, Greenwich. Comet's Geocentric Right Ascension.	Comet's Geocentric Declination.	Log. dist. of Comet from ☉	Log. dist. of Comet from ♁	Comet's Intensity of Light.	Comet's meridian passage. Mean time Greenwich.
1851.	° ′ ″	° ′ ″				h m
Sept. 10	90 25 27	S. 20 5 3	0·0933	9·9601	0·782	18 47
15	97 0 11	19 45 5	0·0705	9·9360	0·970	18 54
20	104 5 6	19 8 11	0·0456	9·9139	1·200	19 3
25	111 39 39	18 10 37	0·0213	9·8946	1·473	19 14
30	119 41 11	16 48 50	9·9948	9·8792	1·787	19 26
Oct. 5	128 5 41	15 1 45	9·9672	9·8686	2·130	19 40
10	136 46 57	12 51 14	9·9390	9·8639	2·479	19 56
15	145 37 28	10 22 20	9·9106	9·8660	2·799	20 11
20	154 29 24	7 44 21	9·8830	9·8750	3·047	20 27
25	163 15 45	5 8 38	9·8576	9·8910	3·183	20 42
30	171 49 54	2 46 30	9·8364	9·9129	3·173	20 57
Nov. 5	181 44 4	S. 0 28 2	9·8193	9·9451	2·960	21 13
10	189 35 12	N. 0 54 7	9·8141	9·9749	2·643	21 24
15	197 0 28	1 45 12	9·8180	0·0055	2·254	21 34
20	203 57 17	2 8 45	9·8305	0·0357	1·851	21 41
25	210 24 14	2 10 28	9·8499	0·0646	1·482	21 47
30	216 21 25	1 56 51	9·8741	0·0915	1·171	21 51
Dec. 5	221 50 3	1 33 28	9·9012	0·1164	0·922	21 53
10	226 52 19	1 4 56	9·9294	0·1390	0·730	21 53
15	231 30 36	0 34 27	9·9578	0·1596	0·582	21 51
20	235 47 19	0 4 28	9·9856	0·1780	0·471	21 49
25	239 44 26	S. 0 23 33	0·0125	0·1946	0·385	21 44
30	243 24 0	0 48 42	0·0382	0·2094	0·320	21 39
1852.						
Jan. 5	247 26 31	1 14 28	0·0674	0·2250	0·260	21 31
10	250 32 48	1 31 58	0·0903	0·2363	0·222	21 24

The maximum of the intensity of light, viz. 3·197, would be Oct. 27th. In 1846 it was as follows :—

Feb. 26..	5·213
March 10 (max.)	6·447
,, 27....................................	5·036
April 1	4·362
,, 22 (last observation)	2·101

Observations made at the Observatory of Highfield House on Zodiacal Light. By E. J. Lowe, *F.R.A.S.*

As a new feature has, I believe, been discovered in the western light during the series of observations made here, a short extract has been deemed of sufficient interest to present to the Association. The latitude and longitude of this place are, lat. 52° 57′ 30″ N., Long. 1° 10′ W. The annexed records show,—1st, pulsations of light

of greater or less brilliancy, occurring at stated intervals; 2nd, an expanding and contracting of the whole body of light, not only vertically, but also laterally; and 3rd, a motion amongst the stars.

1st. Pulsations were noticed 1850, March 6d. 7h. 42m., of greater and less brilliancy in periods of 30s.; in these alternations it invariably receded to a certain dimness, and then brightened again to a fixed extent. The pulsations were again noticed on March 7th, 9th, 10th, 11th; 1851, January 27th, March 20th (when they were very marked), and 22nd. These pulsations were again 30s., alternating from change to change, as they were last year.

2nd. The vertical expansion and contraction of the body of light on 1850, March 6d. at 7h. 42m., were 4° 30′. The longitude of apex, when most brilliant, was ♉ 21° 30′, receding to longitude of apex ♉ 17° when least bright. In 1851, March 20d. 8h., this expansion and contraction were 3°; the max. long. of apex being 51°, min. long. of apex 48°, the mean long. of apex being 49° 30′.

At three different periods the lateral body of light also widened, and this occurred each time when at its maximum degree of brilliancy. This was first noticed at 7h. 55m., when the north edge extended to β Arietis, again at 7h. 59m., when it extended midway between β and α Arietis, and thirdly at 8h. 3m., when it covered α Arietis. It remained in this widened state from 1s. to 3s., returning each time to its mean place between β and γ Arietis; once when very dim the north edge was thought to have receded to γ Arietis (viz. at 7h. 50m.). The southern edge unfortunately had not such good guide stars for measuring, so that I cannot speak positively as to whether it receded when the north edge advanced, yet the impression made at the time was that it did not, and at 7h. 59m. appeared to widen with the north edge.

3rd. Its path amongst the stars.

1850. February 13d. 7h. 30m., Saturn was 2° within its S. edge. Its apex had an altitude equal to that of the Pleiades.

1850. March 6d. 7h. 42m. S. edge confused, appeared to pass through ξ Ceti; α Ceti was 2° within the edge. The N. edge, tolerably bold, passed through ϱ Piscium, midway between γ and β Arietis, and 1° S. of δ Arietis.

1850. March 7d. 8h. 0m. N. edge extended to β Arietis.

1850. March 10d. 7h. 50m. N. edge extended to α Arietis.

1850. March 11d. 7h. 59m. N. edge half-way between α and β Arietis. S. edge just N. of μ Ceti. ξ Ceti about 2° within the edge.

1850. March 12d. 8h. 0m. N. edge between α and β Arietis, slightly nearer β than α.

1850. March 13d. 8h. 0m. N. edge between α and β Arietis, yet still nearer β.

1851. January 27d. 7h. 0m. N. edge passed near α Pegasi.

1851. March 20d. 8h. 0m. N. edge passed midway between β and γ Arietis, the S. edge cut μ Ceti.

The following are the approximate positions of the northern edge at a mean altitude equal to α, β, and γ Arietis:—

Epoch.			Æ.	N. decl.	
1850.	March	6d.	1° 46½′	18° 40′.	Motion direct.
—	—	7d.	1 46½	20 5	
—	—	10d.	1 59	22 45½	
—	—	11d.	1 52½	21 25½.	Motion retrograde.
—	—	12d.	1 51	21 10	
—	—	13d.	1 49	20 50	
1851.	March	20d.	1 46½	18 40	

Extra Remarks.

Epoch 1850. February 13d. 7h. 30m. Exceedingly brilliant, being brighter than the galaxy about the Swan. Saturn was thought to be dimmed by it.

Epoch 1850. March 6d. 7h. 42m. Extent of base on horizon 36°; its S. edge cut the horizon 13° S. of W., and its N. edge 23° N. of W.; axis slightly N. of Pleiades, and horizon 5° N. of W. The S. edge somewhat confused. The alternations in brightness were first noticed by several small stars being alternately visible and invisible;

it was not changeable like aurora borealis, for it invariably receded to a certain dimness, and then brightened up to a certain extent.

Epoch 1850. March 7d. 8h. 0m. Not so brilliant.

Epoch 1850. March 8d. 7h. 15m. Pale and confused.

Epoch 1850. March 9d. 7h. 55m. Brilliant for a few minutes.

Epoch 1850. March 10d. 7h. 50m. Brighter than last night.

Epoch 1850. March 11d. 7h. 59m. Fainter.

Epoch 1850. March 12d. 8h. 0m. Fainter.

Epoch 1850. March 13d. 8h. 0m. Yet fainter.

Epoch 1851. January 22d. 6h. 30m. Apparent, but confused.

Epoch 1851. January 23d. 7h. 0m. Tolerably brilliant by fits.

Epoch 1851. January 27d. 7h. 0m. Brilliant by fits.

Epoch 1851. March 20d. 8h. 0m. Edges well-defined. Extent of base on horizon 23° 30′. The S. edge cut horizon 1° 30′ S. of W.; the N. edge 22° N. of W.; axis 15′ N. of Pleiades, and horizon 10° 15′ N. of W.

Epoch 1851. March 22d. 8h. 0m. Pale and confused.

The evenings in February and March were much clouded in 1851.

On Air-bubbles formed in Water. By JOHN TYNDALL, *Ph.D.*

The object of the paper is to account for the bubbles formed when water is poured into water. Venturi imagined that they were due to the air which adheres to the descending fluid. Magnus, on the contrary, conjectured that they were owing to the formation of a cavity at the point where the descending water meets the fluid underneath, the cavity being closed up, and the bubble formed when a motion is imparted to the surface. This latter conjecture the author proves to be correct, and shows further the relation which subsists between the production of the bubbles and the structure of the descending mass.

A vein issuing at a moderate velocity from a circular orifice in the bottom of a tin vessel possesses two portions strikingly distinct. After the fluid leaves the orifice it is steady and limpid for some distance, and contracts gradually as it descends. The contraction depends upon the accelerated motion of the particles, and its amount depends upon the cohesive power of the fluid experimented with. At a certain point the steadiness of the vein ceases, and it exhibits a quivering motion like the vibration of a harp-string. If the surface of the water underneath intersect the vein *above* this point no bubbles are produced; below this point they invariably appear. The steady portion of the vein exhibits the exact deportment of a solid rod; there is even capillary attraction at the point where it enters the fluid below; and if the oblique light of a candle be suffered to fall upon the eminence here formed, a moth-like figure with yellow wings is thrown upon the bottom of the vessel which contains the fluid. Similar figures are caused by the bubbles which float accidentally upon the surface; and when the latter is set in motion the figures stir their wings as if they were alive.

Although to the naked eye the quivering portion of the vein appears continuous, it is not so in reality, as Savart has demonstrated. It is resolved into single drops, and it is the quickness with which they succeed each other which gives the impression of continuity. Placing a platinum wire heated to whiteness between the poles of a small galvanic battery behind the vein, and using an opake fluid, the author found that when the steady portion came between the eye and wire the latter was cut by a dark stripe; but when the quivering portion came into this position the wire glowed uninterruptedly from end to end. It was seen through the intervals between the drops, and the time of transit of a drop was not sufficient to extinguish the impression.

The descent of each drop causes the water to recede on all sides, thus forming a canal into which the air enters, and where it is entrapped by the descent of the succeeding drop, or by the closing up of the mouth of the canal. Exactly the same takes place when we let grains of shot fall successively into the water, or draw a string of beads quickly through it. It is the lateral component of the drop's force which originates the bubble, and even when the jet is continuous, if it vibrate, bub-

bles will be produced. A bow-string will cause the same when immersed in water and pulled out of its position of equilibrium.

The sound of agitated water, which, as a physical phænomenon, appears to have been overlooked hitherto, is the invariable companion of the bubbles. When the continuous portion of the vein is cut by the surface underneath no bubbles are produced, and no sound is audible; but the moment the one appears the other is heard. The sound is in fact almost wholly due to the sudden liberation of the air enclosed in the water; the ripple of a brook and the roar of the ocean being alike referable to this cause.

On our Ignorance of the Tides. By the Rev. W. Whewell, *D.D., F.R.S.*

The leading features of the *general* knowledge of the tides, at which we arrive by observations, are the succession of times of high water and low water as we proceed along an extensive coast, or from one part of a large ocean to another; and the relative amount of solar and lunar tides, as shown both by the relative heights of high and low water, and by the amount of the semidiurnal inequality of time. To this may be added the amount of the diurnal inequality, and its *incidence*; namely, whether it falls most on high water or low water, on heights or on times.

Such knowledge we possess with regard to the coasts of Europe, pretty completely, mainly owing to the very general system of simultaneous observations made at Dr. Whewell's suggestion in 1826; and also with regard to the Atlantic coast of the United States, our knowledge in that case being entirely supplied by the set of observations made on that coast at the same time. We possess also a tolerably complete knowledge of this kind for the eastern coast of Australia, and for some other points of the coast, the diurnal inequality being here peculiar. We know also the general course of the tides on the shores of New Zealand, which may be expressed by saying that the tide-wave comes from the east, and strikes the middle of the eastern shore first.

And this seems to be the whole amount of the general practical knowledge which we possess on this subject. There appears to be no other extensive coast on which we know the succession of times of high water, still less the semidiurnal and diurnal inequality. On the eastern coast of South America we do not know this with any certainty, though we know that the tides on that coast have curious features; as for instance, that at the mouth of the Plate river the tides are insensible, and a little further to the south, are some of the greatest in the world. But we do not know on what part of the coast the tide-wave runs south, and on what part north.

On the west coast of South America we labour under the like ignorance. It appears to be made out by the observations of Capt. FitzRoy and others, that on the southerly part of this coast the tide-wave runs southward, and so round Cape Horn to the eastward, although it might have been expected that the tide, following the moon, would travel westward. But as we proceed northwards along the west coast of America, it becomes more difficult to reconcile the separate observations which we have. I have supposed that from the isthmus of Panama, the tide-wave diverges northwards and southwards; but in some of its results this supposition is far from satisfactory. For the northern parts of the N. Pacific, we have Admiral Lütke's observations at the Aleutian islands, &c.; but these, though correct as far as they go, only give a partial view.

Returning to the borders of our knowledge, we find that it ends with the shores of Europe. On the west coast of Africa, we know nothing, so far as I am aware, of the progress of the tide-wave; whether it travels from south to north, or from north to south; or where these directions diverge or converge. On the eastern coast of Africa, our ignorance is still more complete; and though we have some detached observations on the coast of India, we have nothing which gives us a correct view of the progress of the tide. Eastward of India we have remarkable cases of the diurnal inequality (Tonquin, Sincapore), noticed from the earliest to the latest periods of tidal researches, but no connected knowledge; and as we go further, the tides of the Indian Ocean and of the Pacific become so mingled that we cannot expect to disentangle them except by laborious observations.

As we are thus ignorant of the progress of the shore tides (the littoral tides), so

are we also of the relation of the central oceanic tides to these. The tides of the Bahamas, the Azores, the Feroe Isles, the Cape Verde Isles, have not been studied, nor connected with each other, nor with the littoral tides. A few notices of what is called "the establishment," tell us little, and it may be, nothing, if we do not know the manner in which these results have been obtained. The same is true of the islands in the central regions of other wide oceans.

It may appear at first sight that this representation of our ignorance is inconsistent with the results formerly furnished as the amount of our knowledge, exhibited in maps of cotidal lines. But to this, I reply, that the cotidal lines, so far as they are drawn across wide oceans, are fallacious. It appears to be certain that the relation of the tidal movements of a large ocean, such as the Atlantic, the Pacific, or the Indian Ocean, are not justly represented by the notion of waves bounded by such lines. With regard to the shores, the motion of the tides may be rightly represented by such lines; but the lines formerly drawn on the various shores above mentioned, merely as the best first approximation which could be made, are still liable to great doubt in almost every place, and therefore they require revision and correction, or confirmation. And this is especially the case, now that these systems of cotidal lines are no longer supported by the kind of connection which their continuity through the oceanic spaces formerly gave them. By means of given *connected* observations (the connexion in the mode of making the observations is the essential condition of success), the course of the littoral tide-wave on all the extensive shores of the ocean might be determined, and at the islands; and these results being obtained, the motion of the tidal movements of the ocean on the larger scale would probably be brought into view.

It may be proper to point out a little more in detail the kind of facts which would have to be noticed. If we suppose a tide-wave, which is nearly straight, moving transversely, to strike a convex shore, there will be some one point which it will first touch, and it will proceed from this point along the shore both ways. This point will be a *point of divergence*; the tide will be later and later both ways in proceeding from this point. Such a point is the S.W. point of Ireland, the Land's End in England; a point on the E. coast of Australia, in S. latitude 25°; a point on the E. coast of New Zealand, in latitude 37°. On the other hand, if the tide come from two different quarters, as for instance if it come round the two ends of an island to the side furthest from the tide, the two waves will approach and meet at some intermediate point of the coast, and there will be a *point of convergence*; and the tides will be later and later in proceeding towards this point. Such a point there is on the coast of England, about the mouth of the Thames, where the tide which comes round by the North of Scotland and by the straits of Dover meet. Such a point there is on the west coast of New Zealand.

Now in order to determine the general course of the tides, we ought to determine these points of divergence and of convergence on every coast, and especially on every extensive coast. But as yet I am not aware that any others are known besides those which I have mentioned. On the west coast of America I have placed a point of divergence near Panama, as best representing the succession of the tides along the coast; but the form of the wave is not satisfactory. On the east coast of South America, as I have said, we have very high tides south of the river Plate, which seems as if there were a point of convergence in that region; but this requires to be more fully proved: and the point of divergence seems to be on the coast of Brazil, but the evidence is very confused and scanty. On the west coast of Africa, I am not able at all to fix upon points of divergence and convergence; and, in short, we know little or nothing of the course of the tides on that coast. Still more is this the case with regard to the Indian Ocean, although on the shores of the great islands which lie there, there must be many points of divergence and convergence.

And the connection of the tides of small islands in a larger ocean with those of the shore is so obscure hitherto, that I do not now venture to express it in any definite manner till we have a better collection of facts. In my paper on the tides of the Pacific (Art. 12.), I have suggested a mode in which this connection may perhaps be expressed.

Meteorology.

Account of an Apparatus for determining the Quantity of Hygrometric Moisture in the Air. By Dr. Andrews.

The object of the author was to contrive an apparatus capable of giving directly the amount of moisture in the air by the unerring indications of the balance, and which might, at the same time, be easily employed in the physical cabinet, or other place devoted to meteorological observations. For this purpose, according to a method long known to chemists, a given volume of air is drawn through a weighed U-tube filled with some substance retentive of moisture; but the author proposes certain modifications in the apparatus hitherto employed which are designed to render it applicable in the hands of persons not familiar with chemical operations, or who may not have the convenience of a laboratory within reach. With this object in view, he found it necessary to reject both sulphuric acid and chloride of calcium as desiccating agents, in consequence of their being either too troublesome in the preparation, or unsafe in the vicinity of valuable instruments; but an excellent substitute presented itself in calcined sulphate of lime or gypsum, which he ascertained by numerous experiments to be capable of removing every trace of moisture from air passed even in a tolerably rapid current through tubes containing it. The sulphate of lime was employed in small fragments prepared by moistening powdered alabaster, as commonly used by plasterers and moulders, and spreading the moistened mass into the form of thin plates, which were afterwards rendered perfectly anhydrous by being placed on an iron plate heated nearly to obscure redness. The aspirator consists of a gasometer whose bell is attached as a counterpoise to the weight of a Dutch clock, sufficiently heavy to work it, by which simple contrivance a known volume of air may be drawn at a uniform rate, and in any required time, through the desiccating tube. The quantity of moisture in the air may, in this way. be determined to almost any degree of accuracy, either for short periods, as half an hour, or for longer periods, as 8, 12 or more hours, in which latter case the apparatus becomes a sort of integrating hygrometer, by which the total amount of moisture in the air for a given period is indicated.

Sketch of the Climate of Western India. By Dr. Buist, *LL.D., F.R.S. L. & E.* (*Communicated by* Col. Sykes.)

The author in this paper abstains from numerical details, and states as his reason for doing so, that the "profuse employment of instruments occasions to a considerable extent the more striking and obvious manifestations of the atmosphere to be lost sight of, unless in so far as these are indicated by the barometer or thermometer;" "and that picturesque and descriptive meteorology has almost altogether been buried under minute instrumental details." He instances Dampier and Mountstewart Elphinstone as furnishing information of the kind he commends.

He first notes that the European division of the year into four seasons, does not hold good in Western India, where the year may be divided into two seasons only, the rainy and the fair, the latter being divisible however into the cold and the hot*. The monsoon sets in at Bombay with tremendous violence from the S.E. in the beginning of June; but the rains immediately go round to the S.W. and draw off early in September. The winds blow throughout the year with the greatest regularity. During the fair season, from October until May, there are alternating diurnal and nocturnal winds, or land and sea breezes as they are called. The land wind blows from easterly quarters, setting in after midnight and blowing until three or four hours after sunrise, when a dead calm ensues. The sea breezes then blow from westerly quarters. About the beginning of May the air becomes damp and muggy; the land and sea breezes become irregular, and a calm prevails over a great part of the night, with the thermometer from 80° to 85°, and the air being surcharged with moisture, people are debarred from sound sleep. About the middle of the month

* *Note by Col. Sykes.*—The Mahrattas divide the year into three natural seasons—the Pâwsalla (rainy), Hewalla (cold) and Oonalla (hot).

long banks of electric clouds make their appearance over the mountains in the East [the Deccan Ghauts]. Towards the end of the month sheet-lightning appears from these clouds, then brilliant lightning, and in time the monsoon opens from them. These masses are frequently magnificent at sunset, but they seldom appear before mid-day, and are rarely visible very long after sunset. In February and March the ground is so parched that the powers of vegetation appear exhausted; and though a small portion only of the trees and shrubs are deciduous, they all look so shrivelled, brown and stumpy, that it is difficult to believe they will vivify again. About the middle of April, however, there is all at once a magical burst of verdure and vitality amongst ligneous plants, as if some new stimulant had been suddenly given, and the forest trees are radiant with flowers, the foot or more long pendent bunches of the yellow flowers of the *Cassia fistula*, and the bright red flowers of the *Erythrina fulgens* being most conspicuous. The delicious mango ripens towards the end of the hot weather, and its turpentine is useful in the cutaneous diseases, boils and entozoa, which then prevail. The author then speaks of the changing seasons upon the habits of birds,—very graphically describes the storms of thunder and lightning, precursors to the setting-in of the monsoon, and the setting-in of the monsoon itself; with its consequences of deluges of rain and green sward; the light of a cloudy English day instead of intolerable glare, and a fall of 10° or 12° in the temperature; cloth and woollens being substituted for cotton and muslin fabrics. He notices the almost miraculous appearance of the multitudinous gigantic yellow frogs, before unseen; notices that boots, shoes and other articles of leather are covered with mildew in the course of twenty-four hours in the houses, and that paper and clothes are damp and clammy. Thousands of small fish, after the first rain-fall, are found in puddles, whether on the plains or on the hill tops, and they appear and disappear with the rains, never exceeding the length of the fore-finger. The rank growth and decay of vegetation evolves immense quantities of carbonaceous gases, which impregnating the water, dissolve the shells and calcareous matter everywhere about; and as the rains draw off and the water evaporates, lime is thrown down, cementing together gravel and other matters into a kind of concrete building-stone. A rain-table for thirty years is then given, showing that the annual fall has varied from 122 inches to 34 inches, the annual average being 76 inches; but this is for the monsoon only, as an account of the fall of rain between November and June has never been kept. The natives consider the force of the rains to be over by the first full moon in August, and a festival is kept in consequence, and half-deck vessels then venture to sea. The breaking up of the monsoon is in October, when the sun is in the constellation "Hust," or the Elephant; but as the terminal storms come to Bombay from over the Island of Elephanta, Europeans call them the Elephanta. About 3 P.M. vast masses of clouds appear piled upon each other, vivid lightning follows, then a deluge of rain, and at last the sky is left destitute of a cloud. This occurs for three or four times, and then the cold and afterwards the hot seasons set in, and rain is sometimes not seen for months. During the squalls of March and April the barometer usually falls or becomes irregular, and during July it sinks very low; but the bursts in the beginning of June and October which herald in and close the monsoon, seem purely electrical, neither the pressure nor the humidity of the air being materially affected by them. Dr. Buist then notices the varying phases of the Elephanta in each year, from 1840 to 1850 inclusive. It will suffice to mention that in 1847 the Elephanta was almost abortive in October, but from the 1st to the 5th of November, there was a fall of 3½ inches of rain, to the great discomfort of those who had gone upon the assurance of the usual regularity of the seasons, into their fair-weather abodes. At neither Madras nor Calcutta is the separation betwixt the rainy and fair seasons, anything like so distinct as it is at Bombay; nor at either place is there anything corresponding in violence or sublimity to the outburst about the 6th of June, or the magnificent though brief Elephanta. Some November dust-storms are then described, of which that of the 1st of November 1850 is a type:—"At 4 o'clock in the afternoon dark lurid clouds began to collect over the Ghauts and roll off toward the zenith, in the teeth of the sea breeze. Heavy rain began to fall all along the line of the Ghauts, about half-past 4 o'clock. At 5 P.M. exactly, the storm burst upon the roadstead and fort of Bombay, and then we had

the extraordinary spectacle with which Bombay, once a year or so, presents us,—the sun shining bright and tranquil over Malabar Hill and Colaba,—the S.W. sky tranquil and serene, while large piles of black clouds travel over each other from the N.E. horizon up to the zenith,—violent rain pouring over the Ghauts, some of the shipsin harbour almost on their beam ends; the trees bending and stooping to the storm, the air over the Esplanade darkened with dust, and large branches of trees, leaves, straw and light materials of all descriptions sweeping through the air! This squall, which was one of the most violent while it lasted that we remember, went round by the N.E., and was over in half an hour; a good deal of thunder followed; after which light rain began to fall which continued for some time. Before 9 P.M. everything was as quiet and peaceful as if there had never been a disturbance amongst the elements at all. From Mahabuleshwur* the people saw the whole far beneath them, and the effect was very grand. In one place a cloud seemed pouring out its contents over a space of almost a square mile, while all around was bright sunshine; between the hills and the sea there was a dense cloud, emitting frequent flashes of lightning, and beyond everything appeared quite clear." Dr. Buist concludes with some reflections upon the storms of India, which he resolves into three classes:—1st, the whirling storm or Cyclone, which has been so well illustrated by Mr. Pedington; 2nd, the travelling storm which glides over the country at the rate of 200 to 250 miles a day, pursuing generally a rectilineal path; and 3rd, the storms of simultaneous occurrence, appearing at a fixed date and manifesting themselves at nearly the same point of time over a vast area of surfuce. Instances are then given: he considers the first week in November, the last week of December, the middle of January, the first week of February, and the first weeks of April and May, to have been crisis periods for some years past. With the exception of these periods of disturbances, the fair weather climate is so uniform as not to need notice; the cold season beginning in December and lasting until March, and the hot season commencing in April and lasting until the rains set in. The last half of January, however, and the whole of February, are remarkable for a dry, thin mist during the day, which obscures the horizon; and for the brightness of the nights and heavy fall of dew. In February the sea at night often assumes a magnificent luminous appearance, the breakers being bright as melted silver. In the day-time it is seen to be of a brilliant red colour, which is occasioned by the *Protococcus nivalis*, or, as Dr. Carter supposes, *P. hæmatococcus*. The animalcules affect strong saline solutions, and it is supposed the red rock salt owes its colour to them. Of the lightning, Dr. Buist says it is often of a ruby or of an amethystine purple colour, sometimes greenish, but most frequently white. Dr. Buist concludes his paper with some interesting notices of the habits of the flying fox, *Pteropus Edwardsii*, and land crab, *Thelphusa cunicularis*†.

Hail-storms in India, from June 1850 *to May* 1851. *By* Dr. Buist. *Communicated by* Col. Sykes.

The year 1850 seems in India to have been singularly barren in notable atmospheric phænomena of all descriptions. The monsoon in Western India was remarkably scanty; and at Bombay not a drop of rain fell betwixt the 5th of November and 16th of May, and there seems scarcely to have been a single hail-storm betwixt June and February worthy of record. On the 7th of February hail fell in considerable quantity of the size of pigeons' eggs, at Comoree near Rawah. A wild hail-storm visited Meerut on the 28th of March, the hail-stones being about the size of walnuts; on the 30th hail fell about the size of beans on the Neilgheries 6000 feet above the level of the sea. Heavy showers began to pour down all over Lower Bengal about the 23rd, and so continued for a week, the spring sowings having gone on rapidly and cheeringly. On this occasion a violent hail-storm visited Calcutta; no great damage however was occasioned by it. Hail fell at Secunderabad on the 11th of April and 2nd of May, and on the 22nd of April a hail-storm of terrific violence occurred at Rungpore, near Calcutta, the hail-stones being as large as ducks' eggs. Nearly all the fruit in the districts, hundreds of houses, and a great number of trees were de-

* At Mahabuleshwur on the Ghauts, is a Sanitarium 4500 feet above the sea.

† See the description by Col. Sykes, in the 1st volume of the Transactions of the Entomological Society, p. 181.

stroyed by it. The three largest masses of ice recorded as having fallen in India are—

1st. That mentioned by Dr. Hyne in his tracts published in 1814 as having fallen near Seringapatam in the time of Tippoo Sultan; it was in the size of an elephant, and took two days to melt.

2nd. In 1826 a mass of ice fell in Candeish, which must nearly have been a cubic yard in size; no exact measure was made of it.

3rd. In April 1838 a mass of hail-stones, cemented into one block, fell at Dharwar. It was 19 feet 10 inches in its larger diameter.

These things, on which doubts at one time were cast, no longer seem incredible. In August 1849 a mass of ice fell in Rosshire 20 feet in circumference; it is described in the Edinburgh Philosophical Journal and the *Scotchman* newspaper of the time.

A correspondent writes:—"Since my list of hail-storms I have only had to record one under my own observation, and which occurred about three P.M. at a place called Oomree, seven miles west of Rewah, on the 7th of February last, the hail-stones fully as big as pigeons' eggs. It did not last long, but was very violent, and tore my tent sadly. This village Oomree must have been about the centre, as it did not extend to Rewah east, and only about four miles to the westward, as my camels were about that distance, and had only rain."

"The subjoined account of a violent hail-storm at Meerut on the 28th of April, is from the *Mofussilite* of the 1st instant:—'On Friday last Meerut was visited by a hail-storm of unusual violence. The hail-stones were considerably larger than pigeons' eggs, the usual standard of measurement on such occasions. We regret to hear that much damage was done in the gardens and fields of the station and district. The prospects of the ensuing fruit-season are now reduced to a possibility, and the splendid crops are said to have suffered very severely.'"

"A Jessore correspondent gives rather an unfavourable account of the weather and crops:—'We had a very heavy shower of hail on the 2nd instant, with scarcely any rain; whatever of the latter fell was all dried up by noon the next day. Since then we have had strong south-westerly winds, scorching up and killing everything: the land is like burnt bricks. Young trees and garden-shrubs are dying off in all directions.'"—*Morning Chronicle*, April 14.

"A severe hail-storm visited the Delhi district on the 17th of April, too late, fortunately, to do any injury to the crops. The hail-stones, which continued to fall for more than half an hour, were of large size, and must have done extensive damage had any of the grain been left standing. At present the atmosphere is charged with electricity, and we may expect a few more thunder-bursts before the weather becomes settled."—*Delhi Gazette*, April 19.

"We hear from Hydrabad that that station was visited with a very heavy shower of rain, accompanied with hail, on the evening of the 17th of April. The hail-stones, we are told, were large, so much so as to startle the natives of the place."—*Kurrachee Gazette*, April 23rd.

"A correspondent at Secunderabad writes as follows, under date 5th instant:—'On the 2nd of April we had a slight shower of hail, and on the 11th of last month there was a very severe fall of hail about four miles from this. The sky now looks very threatening, large masses of dark clouds hanging about.'"—*Bombay Times*, May 12th.

"The subjoined account of a terrific hail-storm at Rungpore is taken from the *Englishman* of the 2nd instant: the hail-stones are described as being equal in size to ducks' eggs!—A correspondent at Rungpore says:—'Have you heard of the dreadful hail-storm we had here on the 22nd of this month (April)? It was one of the most terrific ever known in these parts. It destroyed hundreds of houses, and no small number of trees; some old ones which had stood the storms of a hundred years came down. All the fruit in the gardens is destroyed. The hail-stones were as large as ducks' eggs, and the whole station looks like a wreck.'"

Note by Colonel Sykes.—The following is an account of hail-stones of great size which fell at Nottingham:—

"*Violent Storm at Nottingham.*—On Friday afternoon, June 20th, 1851, at three o'clock, a storm of hail and rain, of unusual violence, broke immediately over this town, deluging the streets, and sweeping everything before it. A great mass of water accumulated in Upper Parliament Street, and swept with overpowering force

down Sheep Lane into the market-place, at a time when there was the greatest throng of business, pots and pans, fruit, vegetables, and other things being carried away; and a large stream flowed out of the market-place down Wheeler-gate, filling the low kitchens in its course. The lightning was extremely vivid, and one flash struck a chimney on the south-west corner of Messrs. Hodgson, Gregory and Co.'s lace-factory, Canal Street, and the electric fluid, passing down the chimney shaft, set fire to a quantity of cotton fibre. The room was instantly in a blaze, but it was fortunately discovered by Mr. Hodgson, and put out in a few minutes. Some of the hailstones were three or four inches in circumference, and were in shape something like broad beans. The storm, which was confined almost exclusively to Nottingham, lasted but ten minutes, and was followed by a brilliant evening. A large number of panes were broken, and the low kitchens in the streets, where there was the slightest descent, were filled with water."

On the Alten and Christiania Meteorological Observations.
By JOHN LEE, *LL.D., F.R.S.*

On some Unusual Phænomena. *By* E. J. LOWE, *F.R.A.S.*

1st. An appearance about the sun seen near Highfield House.

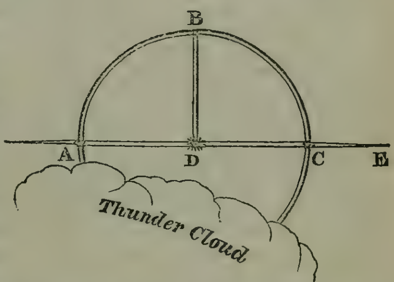
1850, May 28th.—The day had been fine, with passing showers, the barometer above 30 inches.

At $6^h\ 48^m$ the phænomenon was first noticed.

A a mock sun, elliptical, exceedingly bright, highly prismatic, the red being nearest the sun. A ray of light passed through it. The distance from the *true* sun was 24° 30′.

C another mock sun, similar in all respects to A, was formed on the horizontal level of the sun on the E. side.

A B C was a considerable portion of a circle (a part being hid behind a cloud), whose horizontal radius was 24° 30′, and whose vertical radius was 26°.



A D C was apparently a horizontal circle of larger size; it was distinct even to the sun's edge; it passed through the sun, and also through the mock suns. The distance from C to E was 20°, its extreme length was 80°.

B D was apparently a vertical circle, probably of the same diameter as A B C; it was brightest at $6^h\ 53^m$.

At $7^h\ 12^m$ the cloud had risen and covered the sun and mock suns. There was a curious effect from the mock sun C; a glare of light came from behind the cloud similar to the effect produced by a fire behind a hill.

$7^h\ 14^m$ the phænomenon disappeared. It had been apparently formed on the blue sky, as no clouds were visible except those below the sun, and the sky did not even appear dull or hazy.

2nd. An appearance presented by cirri in the daytime resembling aurora borealis. It occurred in 1850, June 4th, at 10 o'clock A.M. An arch of cirrus stretched across from north to south, from which cirri branched off resembling streamers of aurora; upon them were five small clouds, and above this an arch passed from north to south through the zenith; within this arch were wave-like lines, which had pulsations. The phænomenon soon became indistinct. Had the appearance occurred at night, it would undoubtedly have been called colourless aurora borealis.

3rd. Curious appearance in the west after sunset.

1850, July 28th, $7^h\ 10^m$.—The sky scattered over with cirrostrati and nimbi, upon which were six straight and one curved band of orange-scarlet; the latter was formed about over the sun, which had set nearly a quarter of an hour before.

$7^h\ 12^m$ the curved band vanished.

$7^h\ 13^m$ a blood-coloured mock sun formed 5° above the horizon, not dazzling, but of good shape. It seemed to be immediately above the true sun. Lasted 2 min.

4th. Effect in a fog.

1851, January 6th.—Nottingham and neighbourhood was visited by a remarkable fog. At 4^h P.M. the prospect did not exceed 5 yards. The upper stories of houses and tops of trees invisible. On going to an open window, a candle being in the room, my image was very distinct on the fog at a distance of about 3 yards from me.

11^h P.M. mist considerably cleared; the prospect extended to about 60 yards. On going down a steep hill, a lamp, being situated near a house, at a distance of 50 yards, appeared elevated in the air to nearly the level of the eye of the observer; on nearing it, it gradually lowered, until, when opposite, it appeared at its proper elevation.

5th. An appearance of cloud analogous to aurora borealis.

1851, March 29th, $10^h\ 50^m$. Stars bright, nimbi about. Below Cassiopeia was a dense nimbus of a leaden colour, from which proceeded upwards streams of a leaden hue, which precisely resembled aurora borealis; these advanced and receded repeatedly, and dimmed the stars very considerably; between the bands the stars shone brightly. There were no signs of aurora borealis at the time.

Observations on Storms. By ROBERT RUSSELL (*Edinburgh*).

In my communication last year on this subject at Edinburgh, I stated that there appeared to be two distinct classes of storms which occurred in Britain. In both, there were in general two currents in the atmosphere moving in different directions. At that time I described the rainy form of storms in which a western current is flowing above, while the wind at the surface of the earth is blowing from very different points of the compass over the island—often no doubt to a certain extent corresponding to the curves which is supposed to indicate a gyration and translation of the elements of the storms. But I must say that the rotary theory of storms has never been satisfactory to my mind, and I believe that the phænomena involved admits of other explanation. I gave an illustration last year of the slow progress which the rains often make in their northerly course by taking the weather of October 1849 in the north and south parts of the island. While I was actually reading my communication a similar instance was again in action, and producing fine clear weather in Scotland during the end of July and 1st of August, when the equatorial currents were precipitating their moisture over the south of England, and damaging the crops. But on the 18th and 19th of August a storm of wind swept over Britain, and was particularly violent in the north of England and over Scotland. The destruction which occurred to the uncut grain was of a very serious character. It afforded a good example of the other class of storms which I adverted to; and in the present short sketch I only intend to state the more prominent features which distinguish this form of storms from the other, which was described last year. Theoretical considerations will be avoided, as it may form materials for a future communication. It is well known that some storms begin to blow from south-west, and veer round to north-west. It often happens, however, that an upper north-west current has been steadily flowing all the time. During the present season the weather was very cold and stormy in the end of May, and almost throughout the month of June. In these storms the wind began to blow from south-west, and veered round to north-west; but the upper currents kept very regularly in Scotland from the north-west. This is a very common occurrence over Great Britain in autumn and winter: when the wind below veers round to the north-west, it becomes dry and cold, and the clouds clear off; but again the wind will shift at the surface of the earth to the south-west, while the current above will still continue from the north-west. Here we perceive a consistent and regular recurrence of phænomena. The south-west wind is laden with moisture, which is condensed into cloud and rain where the two winds meet. The lower surface of the cold upper current forms cirrostratus, which, when we observe its motions, is the means which assures us of the existence of two different currents. The formation of this particular cloud in the west is the first herald of approaching storm, for the barometer does not give warning here as in the rainy storms with eastern winds; this is a very distinct and important feature in the two.

This is no doubt owing to the change taking place in the one class of storms in the lower strata, while it is taking place in the upper regions in the other. It is also a characteristic of these westerly gales, that the south-west wind, at the surface of the earth in its first stages, crosses the whole island in one broad stream, beginning to blow almost simultaneously in Cornwall and the north of Scotland. The oscillations of the barometer also often correspond as to time, but vary as to amount. It is seldom that much rain falls in the eastern counties under these conditions of atmospheric currents; but it falls copiously in the western, where the lower current is driven up the high grounds, and probably projected into the colder current above. There is no doubt that the upper current from the north-west not only produces cloud, which, so far as our observations extend, is peculiar in shape and form to this course of winds, but it actually acts in many instances as a condenser in throwing down considerable quantities of rain. A good instance of this occurred on the 27th of August, 1850: early on that morning the wind in Fifeshire was north-west and very cold; it fell to a calm below, and a warm moist south-west wind sprang up, and gradually veered round to south-east, east, north-east, and at last to north-west at night. This is by no means a common occurrence, as it usually goes the other way: ·71 inch of rain fell in Fife, and 1·1 inch at Whitehaven, in Cumberland, where it also rained the whole day. When the clouds began to clear away towards night, I observed the cirrostratus lying like vanes pointing north-west to south-east, which was gradually evaporated by the wind when it got round to the same direction. In the more violent storms of wind the upper strata appear to be excessively cold, and the great alterations of temperature which occur are closely connected with this circumstance. The weather was remarkably fine and warm over Britain about the 15th of August: it was the finest day of summer in Fifeshire; the maximum shade temperature rose to 80°. The barometer fell very rapidly on the 18th and 19th at Dunino, with a very heavy gale of wind. A repetition of the gale and fall of the barometer took place on the 25th. In both cases the south-west wind was blowing over the whole island, from Inverness to Cornwall, and when the storm set in an upper north-west current prevailed. The temperature of the higher strata seems to have been intensely cold on the 20th, 21st, 22nd and 23rd; hail-showers were more or less common over the whole island. The cumuli were very low, and the sky of that deep and transparent azure which only occurs in summer, when the sun heats the lower strata of the atmosphere. In Forfarshire and Banffshire devastating storms of thunder, with hail, occurred; the Grampian Mountains were covered with snow in many places.

It is worthy of remark, that on the 18th and 19th of August, when the barometrical pressure was very light in Fifeshire, the north of France and Belgium were visited with great falls of rain, which flooded all the low countries. We have avoided in this short sketch all reference to theory, but on another occasion we may enter upon this ground. In the meantime we close this paper by expressing our opinion that little progress will be made in developing the law of storms until the directions of the wind in the higher and lower strata of the atmosphere are more generally observed and carefully registered.

On some of the Appearances which are peculiar to Sunbeams. *By* Henry Twining.

In this communication, the author noticed the condition of the cloud and the state of the atmosphere which usually give rise to the appearance of luminous beams. He observed that the luminous rays are formed chiefly in the lower regions of the atmosphere, but that they are nevertheless seen at times at very great elevations, since they occur as much as 20 minutes after sunset.

He called attention to the peculiar perspective effects which are connected with the appearance of luminous rays, as they occasionally *seem* to extend in the most opposite directions, although their real direction is invariably the same. Referring to a belt of exceedingly dark shadow which surrounds the luminous margin of clouds, he stated that it differs essentially from the usual appearance of solar radiation, and proposed a hypothetical explanation of this peculiar effect.

Register of Meteorological Phænomena at Huggate in Yorkshire. By the Rev. T. Rankin.

Law of Storms.—On Mooring Ships in Revolving Gales. By Lieut.-Colonel Wm. Reid, *Royal Engineers, F.R.S.*

In this paper I propose to explain a subject which I had overlooked, until my attention was lately drawn to it by Sir James Dombrain, who commands the Revenue vessels on the coast of Ireland. He informed me, that after studying the first work I had published on the Law of Storms, he observed that when he let go his right hand, or starboard bower anchor, the first, and afterwards the left-hand, or port bower anchor, in gales on the coast of Ireland, veering from south-east by south to west, that the cables twisted or fouled as the vessels swung round to the veering wind; and that this observation led him to change all his best bower anchors from the starboard to the port side of his vessels.

This would generally be the rule on the coast of Ireland. But these remarks led me to consider what the rule should be on either side of the centre of a progressive revolving gale, and whether it would not be different in the southern hemisphere, in which gales revolve in the opposite way to what they do in the northern hemisphere. I may here explain, that when two cables are laid out with anchors from the head of a ship, it becomes very difficult to weigh anchor with only one crossing in the cables, and impossible to do so with a double cross, called an elbow; and hence the importance of riding at anchor without crossing or fouling the cables when ships are moored.

Fig. 1.

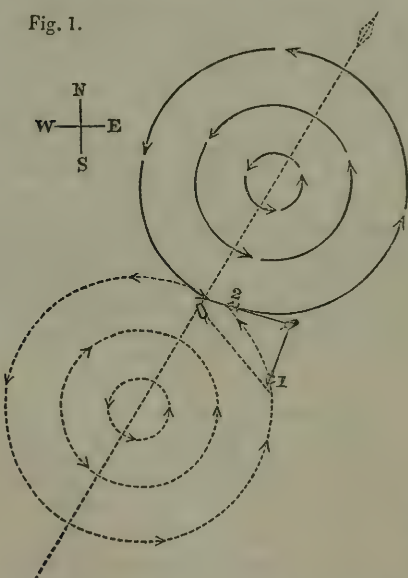


Figure for the Northern hemisphere.

Ship in right-hand side of gale.

The first diagram is intended to represent a whirlwind gale 800 or 1000 miles in diameter, moving on a north-east course, and supposed to be approaching the British Islands, but with its centre on the Atlantic; and such gales are the most frequent on the British coasts. In such a gale as is here represented, the wind on the British coasts would set in between east and south, and veer by the south to the west. If a ship were to come to anchor with a single anchor, as that marked (), with the

wind at south-east, she would at first swing to the north-west, head to wind, as in the diagram; and it is necessary to remark, that both the ships and length of cable, in this and the other diagrams, are unavoidably greatly exaggerated in size, in proportion to the scale of the gale.

As the whirlwind gale moves onwards in the direction of Norway, and as the wind veers towards the south, the ship would swing towards the north, and whilst swinging, by letting go the anchor No. 2 from the starboard bow, she would be moored as in the figure. By inspecting the diagram, it will be seen, that had the starboard anchor been first let go, and afterwards the port anchor, the cables would cross; but if the port anchor had been first let go, the ship would ride with what is called open hawse.

The next diagram will show that the rule just mentioned would not hold good in

Fig. 2.

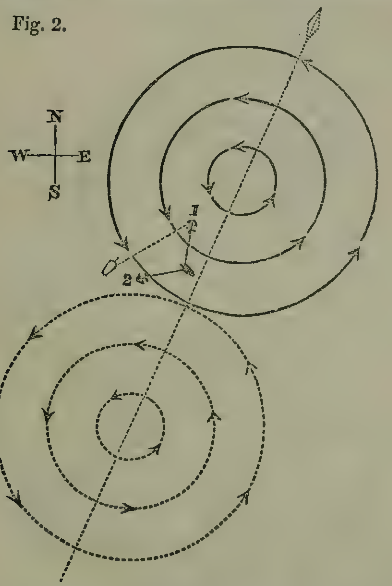


Figure for the Northern hemisphere.

Ship in left-hand side of gale.

cases where a ship comes to anchor at the setting in of a whirlwind gale, and happens to be on the opposite side of the gale's centre to that just described; as for example in the north-east storms of the Atlantic coast of North America, in which the wind veers from north-east to north and north-west. In this case, if the port anchor were to be the first let go, and afterwards the starboard anchor, the cables would foul or cross; and therefore the starboard anchor should in this case be the first let go, to ride with open hawse, as will be best understood by considering the diagram. If a whirlwind storm were moving northward, with its centre skirting the coasts of Holland, the British Islands would be in the left-hand side of the storm, when the starboard anchor should be the first let go.

I have made two other diagrams to show what the effect of the veering of the wind would be south of the equator. From these diagrams we see that ships will ride with open hawse by letting go the port bower anchor first, when in the right-hand side of a cyclone or whirlwind gale; and that they will ride with open hawse by letting go the starboard anchor first in the left-hand side of a cyclone, both in the northern and southern hemispheres, notwithstanding their counter-movement north and south of the equator.

I have been here only endeavouring to point out general principles, which would

require to be modified by seamen according to local circumstances. For example, tides by creating currents sometimes cause ships to swing against the wind.

Fig. 3.

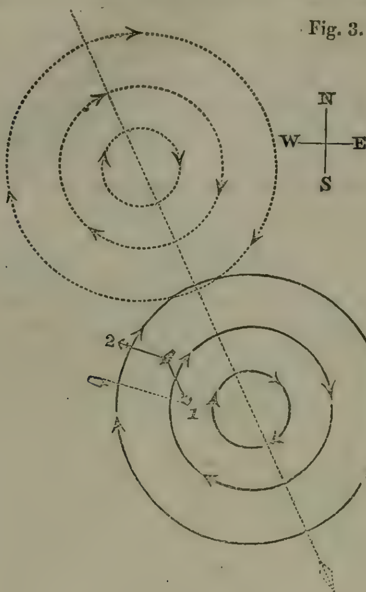


Figure for the Southern hemisphere.

Ship in right-hand side of gale.

Fig. 4.

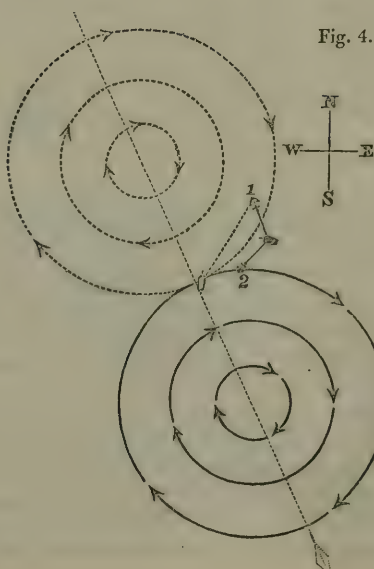


Figure for the Southern hemisphere.

Ship in left-hand side of gale.

Abstract of Mean Pressure, Temperature, &c. for the First Quarter of 1850, from the Register kept at Futtegurh.

1850. Mean for the month of	Barometer reduced to 32° Fahrenheit.*							Temperature of the air in the shade.			Depression of wet bulb in the shade.			Self-registering thermometers in the shade.			Daily extreme variation.	Rain. Inches and decimals.	Dew deposited on one superficial square foot of cotton cloth, colour green, in grains.
	6 a.m.	8 a.m.	10 a.m.	Noon.	4 p.m.	6 p.m.	10 p.m.	8 a.m.	Noon.	4 p.m.	8 a.m.	Noon.	4 p.m.	Min.	Max.	Mean.			
January ..	29·376	29·416	29·460	29·422	29·353	29·365	29·412	50·71	63·17	64·11	2·24	8·03	8·58	46·88	66·30	56·59	19·42	2·60	6·068
February .	29·405	29·446	29·479	29·437	29·363	29·380	29·431	57·42	73·16	73·14	3·91	13·41	13·39	52·10	77·07	64·58	24·96	0·55	3·819
March....	29·252	29·297	29·328	29·303	29·216	29·220	29·275	69·01	85·24	87·03	10·38	22·03	23·72	59·64	89·24	74·44	29·59	0·50	2·320
Sums	88·033	88·159	88·267	88·162	87·932	87·965	88·118	177·14	221·57	224·28	16·53	43·47	45·69	158·62	232·61	195·61	73·97	3·65	12·207
Means....	29·344	29·386	29·423	29·387	29·310	29·321	29·372	59·04	73·85	74·76	5·51	14·49	15·23	52·87	77·53	65·20	24·65		

Abstract of Mean Pressure, Temperature, &c. for the Second Quarter of 1850, from the Register kept at Futtegurh.

	Barometer reduced to 32° Fahrenheit.					Temperature of the air in the shade.					Depression of wet bulb in the shade.					Self-registering thermometers in the shade.			Daily extreme variation.	Max. Thermometer in sun's rays.	Rain. Inches and decimals.	Evaporation from a circular surface of water 5 inches in diam. and 1 inch in depth, in inches and 100dth of an inch.		Dew deposited on one superficial square foot of cotton cloth, colour green, in grains.
	6 a.m.	10 a.m.	4 p.m.	6 p.m.	10 p.m.	6 a.m.	10 a.m.	4 p.m.	6 p.m.	10 p.m.	6 a.m.	10 a.m.	4 p.m.	6 p.m.	10 p.m.	Min.	Max.	Mean.				6 a.m. to 6 p.m.	6 p.m. to 6 a.m.	
April	29·171	[illegible]	[illegible]	[illegible]	29·172	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10·116	21·233	27·233	23·283	15·450	67·984	96·783	82·383	28·800	128·000	a few drops.	16·49	2·36	·779
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25·823	31·290	26·290	18·413	75·887	105·838	90·862	29·951	137·838	a few drops.	21·60	4·86	·349
June	28·827	28·866	28·741	28·736	28·814	83·983	93·800	99·083	96·316	90·216	7·700	15·316	20·166	18·350	13·233	82·633	101·483	92·058	18·850	119·583	0·80	13·47	4·48	·467
Sums	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31·511	[illegible]	78·689	67·293	47·096	226·503	304·104	[illegible]	77·601	385·421	0·80	51·56	10·70	1·595
Means	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20·790	26·229	22·641	15·698	75·501	101·368	88·431	25·867	128·473				

Abstract of Mean Pressure, Temperature, &c. for the Third Quarter of 1850, from Observations made at Futtegurh.

	Barometer reduced to 32° Fahrenheit.				Temperature of the air in the shade.		Depression of wet bulb in the shade.		Self-registering thermometers in the shade.			Daily extreme variation.	Black bulb self-registering thermometer in sun's rays.	Rain. Inches and decimals.	Evaporation from a circular surface of water 5 inches in diam. and 1 inch deep, in inches and 100dth of an inch.		*Dew deposited on one superficial square foot of cotton cloth, colour green, in grains.
	10 a.m.		4 p.m.														
	Temp. Mercury.	Barometer corrected.	Temp. Mercury.	Barometer corrected.	10 a.m.	4 p.m.	10 a.m.	4 p.m.	Min.	Max.	Mean.				6 a.m. to 6 p.m.	6 p.m. to 6 a.m.	
July	86·040	28·934	87·690	28·824	89·472	95·443	12·427	15·310	85·525	97·287	91·406	11·762	122·416	1·91	11·23	3·16	652
August ..	84·064	28·997	85·161	28·900	86·145	87·532	5·951	7·548	79·338	91·435	85·387	12·096	111·500	7·88	7·29	1·06	2·516
September	83·566	29·104	85·666	28·990	86·866	90·533	9·283	12·433	78·166	93·383	85·775	15·216	116·633	9·88	8·98	1·31	2·198
Sums....	253·670	87·035	258·517	86·714	262·483	273·508	27·661	35·291	243·029	282·105	262·568	39·074	350·548	19·67	27·50	5·53	5·366
Means ..	84·556	29·011	86·172	28·904	87·494	91·169	9·220	11·763	81·009	94·035	87·522	13·024	116·849				
4th Quarter of 1850.															7 a.m. to 5 p.m.	5 p.m. to 7 a.m.	
October..	76·064	29·310	80·580	29·193	80·564	85·258	9·000	13·596	68·048	87·354	77·701	19·306	113·854	0·74	7·05	0·52	1·081
November	68·066	29·410	75·533	29·300	72·700	80·100	11·783	16·733	55·000	82·833	68·916	27·833	110·000	a few drops.	6·61	0·92	2·331
December	61·064	29·513	68·387	29·395	63·596	72·435	9·177	14·467	47·145	76·290	61·717	29·145	102·096	a few drops.	5·83	0·88	2·475
Sums.. .	205·194	88·233	224,500	87·888	216·860	237·793	29·960	44·796	170·193	246·477	208·334	76·284	325·950	0·74	19·49	2·32	9·887
Means ..	68·398	29·411	74·833	29·296	72·286	79·264	9·986	14·932	56·731	82·159	69·444	25·428	108·650				

* The corrections applied to the barometer are—
1st. For capacities; and as the neutral point is 29·930, this correction is always minus.
2nd. For capillary action, ·020, which is always plus.
3rd. For reducing the observed temperature of the mercury to 32° F., which is always minus.

Futtegurh, 10th January, 1851.
JOHN C. PYLE.

In a paper read before this Association thirteen years ago, I ventured to point out that meteorology had been studied in far too circumscribed a sphere, and that nations should combine to study the atmospheric laws. Acting on this principle, a very important step has recently been taken by the American minister, Mr. Abbott Lawrence, and Viscount Palmerston, towards putting the consuls of the American and British nations throughout the globe in communication with each other for the furtherance of meteorological investigations. It is proposed that the consuls shall aid their respective navies, both public and commercial, in collecting meteorological facts. Instructions to this effect have been sent by Lord Palmerston to about 200 British consuls; and in these instructions to the consuls it is stated,—"You will transmit to me half-yearly an abstract of the information you may have obtained, with such remarks as may suggest themselves to you. If you can add diagrams, to show the tracts of any remarkable storms, they will greatly add to the value of the reports; and as it is of importance to circulate as widely as possible information as to storm tracks, you should encourage the publication of such information in newspapers and periodical works."

If these instructions be properly carried out, they will prove of high value to meteorological science. The progress hereafter to be made in the study of the atmospheric laws, will in a great degree depend upon periodical publications, widely circulating information from as many points on the surface of the globe as it is possible to obtain it. It has been mainly through the instrumentality of the Bengal Asiatic Society's Journal giving wide publicity to Mr. Piddington's labours, that we are indebted for our present knowledge of the cyclones of the Indian seas.

It had been supposed that hurricanes were unknown at the Cape Verde Islands, yet a very severe one occurred there on the 3rd of last September. By the consular reports, forwarded to me by Lord Palmerston, together with reports from some vessels which encountered it, I find that the storm alluded to came from the eastward, and passed over the Cape Verde Islands, on a westerly course, as a whirlwind storm. The Cape Verde Islands are in lat. about 16° and 17° north. It was afterwards encountered in lat. 28°, long. 32°, which shows that it took from the Cape Verde a north-west direction. If it continued its progress it must have passed to the westward of the Azores.

In such an inquiry, negative proof, if I may here apply the term, is of great value; and it has been satisfactorily proved from reports called for by the Foreign Office, that this storm did not pass between the groups of islands on the eastern side of the Atlantic. But the reports from Mr. Carew Hunt, consul at the Azores, lead to the belief that it did pass on the 12th of September to the westward of his position. I have alluded to this Cape Verde Islands hurricane, in order to show the great importance of having observations over extensive spaces of the globe, in studying the atmospheric laws.

It is generally known that for some time back, the direction of the wind has been reported to the Electric Telegraph Company, from all the points in Great Britain with which their wires communicate; but the atmospheric pressure was not given. Within these few days, however, this very valuable addition has been made by the Electric Telegraph Company.

Should the attempt now making to lay down electric telegraph wires across the Straits of Dover be successful, we shall be able to obtain in this country simultaneous reports on the veering of the wind, in combination with the alterations of atmospheric pressure over all parts of Europe. We should then be able to track the storms of the Mediterranean Sea, over Europe to the Baltic; and I have great pleasure in being able here to state, that there is reason to hope that the French in Algeria have engaged in this inquiry, with a view of tracing the Mediterranean storms to their source in Africa.

Abstract of Meteorological Observations made at Futtegurh, for the Year 1850, *North-West Provinces, Bengal. By* JOHN C. PYLE. *Transmitted by* Dr. BUIST, *and communicated by* Lt.-Colonel SYKES, *F.R.S.*

Description, position, &c. of the instruments employed:—

Barometer.—Frame wholly of metal; iron cistern for holding the mercury, with

thermometer inserted; scale from 27 to 31 inches; vernier moved by rack and pinion; made by Newman, 122 Regent Street, London, and imported to direct order in May, 1848. This instrument is placed inside the house, in a room facing S.W. by S.

Dry and wet bulb Thermometers, 1, 2.—Made by Newman, and received direct from him. Ivory scales, graduated to single degrees, half-degrees estimated.

Self-registering Thermometers, 3, 4.—Made by Newman, and received direct from him. Metal scales, graduated to half-degrees. These four thermometers are placed in a thatched shed 20 feet by 13, in which there is a free circulation of air. The shed is at a short distance from the house.

Black bulb self-registering Thermometers.—Made by Newman, and received from him in 1850. Metal scale, graduated to half-degrees, fixed 4½ feet from the ground, facing south, fully exposed to the sun, and at a distance from the house.

Rain-gauge, made by Newman.

Note by Dr. Buist on the Meteorology of Futtegurh.—The following tables furnish an abstract of the meteorological observations taken by Mr. J. C. Pyle at Futtegurh. Mr. Pyle is an able, an old and experienced meteorologist. His instruments seem of the best quality and in good order, and the correctness of his observations may be relied on. For the first half of the year readings were taken at 6 and 10 A.M., at noon and at 4, 6 and 10 P.M., thus giving three of the turning-points of the barometer, borastices as we call them in India. The 6 o'clock observation gives a close approximation of the fourth. It is unfortunate that for the latter part of the year Mr. Pyle should have given readings at 10 A.M. and 4 P.M. only. Futtegurh, in lat. 27° 21′ N., long. 79° 31′ E., is the northernmost station in India, so far as I know, from which observations so full as those of Mr. Pyle have been received. The Simlah observations have not yet been laid before the world. The following are the means of the various months of the year:—

Jan.	29°·400.	April	29°·116.	July	28°·389.	Oct.	29°·250.
Feb.	29·420.	May	28·916.	Aug.	28·448.	Nov.	29·355.
March	29·270.	June	28·771.	Sept.	28·513.	Dec.	29·389.

It will thus be seen that the barometer obtains its maximum, as in most places of India, in February, and its minimum in July, the rain during the year being 24·86 inches. The daily range of the various months seems the following:—

Jan.	·017.	April	·131.	July	·110.	Oct.	·117.
Feb.	·116.	May	·129.	Aug.	·097.	Nov.	·110.
March	·112.	June	·152.	Sept.	·114.	Dec.	·118.

These ranges are unusually high for a latitude so far north as Futtegurh, and they depart considerably from the general law by which the daily range diminishes as the barometer sinks. The June and July ranges, when the mercury was at its lowest, are higher, or nearly as high, as those of January and February, when the pressure was greatest. When we find anomalies of this class in the northern hemisphere, with others still more striking just south of the line, at St. Helena for example, where the mercury is almost stationary, how earnestly does the meteorologist long for more observations, or speedy access to those which have already been made! Simlah, Sincapoor, Lucknow, Bombay, Trevandrum, have all treasures in this way requiring to see the light.

Note by Colonel Sykes on the Meteorology of Futtegurh.—Mr. Pyle appears to have had trustworthy instruments, and to have made a careful and laborious use of them. I presume he has not had any opportunity of comparing them with standards, nor does he mention the elevation of Futtegurh above the sea; but it cannot be less than 600 feet, as the maximum mean pressure on the barometer in February was only 29°·420; but as Mr. Pyle would seem to have taken a mean of means for his quarterly determinations, in case he has followed the same plan in fixing his monthly means, 29°·420 may not be quite accurate. The annual curve of pressure would appear to be regulated by the place of the sun in the ecliptic, as I showed was the case in my paper on the Meteorology of India, in the annual curves of pressure at Bombay, Madras and Calcutta. The mean depressions of the wet-bulb seem to have been always greatest at 4 P.M., diminishing with decreasing temperature, and increasing with the temperature. The depressions must have been very marked in

the month of May, since the *mean* depression for the month at 4 P.M. was 31°·29' the mean temperature at that hour being 103°·35, which by Glaisher's factors would give a dew-point of 56°·4, or nearly 47° below the temperature of the air. Apjohn's formula would make the dew-point 53°·4, or 50° below the temperature of the air. The *mean* temperature of 103°·35 at 4 P.M. in May far exceeds anything I ever experienced in India. The fall of dew was greatest in the first and fourth quarters of the year, when the mean temperature is lower than during the other two quarters; but the greatest quantity of dew did not fall in the coldest months, with the exception of January. The evaporation was necessarily greatest in the hot quarter; but somewhat singularly the next greatest amount was in the Monsoon quarter, when nearly 20 inches of rain fell.

Notice of Aurora Borealis seen at St. Ives, Hunts, Oct. 1, 1850. *By* J. K. Watts.

The phænomena consisted of flashes, chiefly red, which often rose to the zenith. There was no arch. The appearance lasted from 8·55 to 9·15.

Notice of a Snow-Storm. By J. K. Watts.

A remarkable thunder-storm, accompanied with *snow*, passed over the town of St. Ives, Hunts, on Wednesday the 21st of August, 1850. For several previous days the state of the weather had been unfavourable, with heavy rains and strong winds, doing considerable damage to the corn crops in the neighbourhood, some of which were entirely destroyed. On the morning of the storm, however, the sky remained clear, a cold wind blowing directly from the north, until about 11 o'clock A.M., when the wind, after shifting to and from all points, suddenly veered round to the south-east, bringing masses of heavy cloud, apparently highly charged with electric fluid. This state of the atmosphere continued till 1 o'clock P.M.; cold rain falling at intervals with three distinct currents of air, the upper and lower of them blowing from the south-east with a great volume of dense rolling vapour, and the middle one from the opposite direction, viz. the north-west, driving thin light cirro-cumulus clouds before it with great rapidity. At about 2 o'clock a large black cloud approached the town from the south-east, preceded by an extremely cold current of air. The thermometer fell rapidly, and there was every sign of great atmospheric commotion. When the storm approached the town, *a large quantity of snow fell covering the roofs of the buildings to some depth,* and vivid discharges of electric fluid took place, with deafening reports of thunder. This was followed by a driving shower of hail of large dimensions, and a most piercing wind, the air being very oppressive as though charged with *sulphureous vapour*. The wind then veered to the south, driving the storm rapidly away towards the villages of Broughton and Ripton-Regis, where pieces of ice fell of a large size, doing great injury to vegetation.

When the storm had subsided one current of air only was perceptible, as the whole body of vapour travelled in one direction towards the north-west. In the evening the weather cleared up and the atmosphere became warmer.

Account of a Lunar Rainbow, seen Aug. 23, 1850, *between Haddenham and Earith, near St. Ives. By* J. K. Watts.

The weather had been somewhat tempestuous for several days previously, with cold rains and variable winds, and on the preceding night the moon was at the full. On the night in question, the sky presented a most singular appearance: from the horizon in the north-east across to the north-west, it was perfectly clear, the moon and stars shining brilliantly; while extending from the south-east to the north-west and down to the horizon was one continuous mass of black cloud, so that one half of the sky was quite light and cloudless, and the other half intensely dark. At about 10 o'clock some small rain fell, evidently from the edge of the cloud above me, and it was clearly perceptible that at a short distance from the spot where I was, it rained heavily. Presently a broad and silvery-white arch appeared, being completely semicircular; and directly after, a second or outer bow, as perfect in every respect as

the inner one, was also formed: both were as clearly and perfectly developed as any solar bow I have ever seen. They were exceedingly brilliant, and by having a dense sombre back-ground, had a most magnificent appearance: several colours were perceptible upon their outer edges, but only in a faint degree; tinges of red and blue were most distinct. The phænomenon continued in its greatest perfection for a quarter of an hour, during which time it attracted the notice of other persons, as I was afterwards informed. It appeared to be but a short distance from me, and was at least 20 minutes disappearing from the time of its greatest brilliancy, thereby showing the slow progress made by the shower.

On the Rise and Fall of the Barometer. By W. H. WEBSTER.

Description of a Sliding-Rule for Hygrometrical Calculations. By JOHN WELSH, *Kew Observatory.*

This instrument has been devised with the view of facilitating the reduction of observations with the dry and wet bulb hygrometer.

The results usually deduced from the observations of the dry and wet thermometers are,—1st. The elasticity of the aqueous vapour present in the air. 2nd. The temperature of the dew-point. 3rd. The degree of humidity, or the ratio to complete saturation. 4th. The weight of water contained in a cubic foot of air.

The first of these results is deduced from the well-known formula of Dr. Apjohn, $f''=f'-\frac{d}{87}\cdot\frac{h}{30}$, where f'' is the elasticity of vapour required to be found, f' the elasticity corresponding to the temperature of the wet thermometer, d the difference between the dry and wet thermometers, and h the height of the barometer. The dew-point is the temperature corresponding to the elasticity f''. If f be the elasticity corresponding to the temperature of the air, the degree of humidity$=\frac{f''}{f}$. The weight of vapour is obtained from the formula

$$w'=\frac{1{\cdot}375\times 258{\cdot}448\times E_t}{30\,(1+{\cdot}002083\times \overline{t''-32})}\text{*},$$

where w' is the weight in grains of the water contained in a cubic foot of air at a dew-point t; E_t the elasticity of vapour for the same temperature. A factor has to be applied to w' in order to correct for the increased elasticity of the vapour due to the depression of the dew-point below the temperature of the air.

The observer, in obtaining these four results, has to make distinct calculations for each observation, making six references to tables, and performing one subtraction, one multiplication, and one division. By means of the instrument about to be described, it is believed that the four results mentioned above can be obtained with less trouble, and with as much accuracy as the observations themselves can be taken.

The instrument is a sliding rule, about 15 inches long, and 1½ inch broad, having one sliding-piece on each side. Figure 1 in Plate I., is a plan of a portion of the instrument drawn to the natural size; the sliding-pieces being set in accordance with the example given below. On the first side, the scale A is one of equal parts, its argument being the elasticity of vapour in inches of mercury; one-tenth of an inch of mercury being represented by one inch in the scale. The fixed scale D shows the corresponding temperature according to Dalton's table; this scale being of course an unequal one. Scales B and C, similar to D, are divided upon each edge of the sliding-piece which works between A and D. In the middle of the sliding-piece are three slits having bevelled edges; on each side of these slits are divided short scales a, b, c, d, e, and f, representing the quantity $\frac{d}{87}\cdot\frac{h}{30}$, which has to be subtracted from f', in order to give f''. The scales a, b, c, d are adapted for each half-inch of the height of the barometer from 29 to 30½; e and f being adapted to the change which takes place in the coefficient when the temperature of evaporation is below

* See Greenwich Mag. and Met. Observations, 1842, p. xlviii.

32°, and for the heights 29 and 30 inches of the barometer. The indices *i*, *i*, *i*, seen through these slits and drawn on the fixed portion of the instrument, are so placed that when the slide is closed they shall point to zero of all these short scales. When the slide is closed the scales C and D should coincide, and the scales A and B should have the correct tabular relation.

On the other side of the instrument there is another sliding-piece. The scale H on one edge of the sliding-piece is a simple logarithmic scale, the argument in this instance being the degree of humidity, saturation of the air being=1·0. The fixed scale I opposite to this is also logarithmic, and represents the logarithm of the elasticity of vapour; the argument, however, being the temperature corresponding to the elasticity.

The scale E on the other edge of this sliding-piece is one of equal parts, and represents the temperature of the dew-point. The fixed scale F is the weight in grains of the water in a cubic foot of air corresponding to the temperatures in E. On a line with F is a short scale G, which gives the correction to be applied to the numbers in F for the depression of the dew-point below the temperature of the air; the argument being the number of degrees of this depression. An index *g* is placed so, that when the slide is closed, and the scales E and F are in correct tabular relation, it shall point to zero of scale G. The scales E, F, and G ought in strict accuracy to have been in logarithmic relation to each other; but it was found, on trial of extreme cases, that they are already (owing to the laws of change of elasticity) so very nearly so, that no appreciable error is introduced by the approximate method adopted.

The use of the instrument will be best understood from an example. Let the dry thermometer read 70°, and the wet 65°, the difference is 5°; let also the height of the barometer be about 29·5 inches.

Move the first sliding-piece (B C) until the index *i* is opposite 5·0 on scale *b*; look for the division 65°·0 on scale B; opposite 65 will be found on scale A ·561 in. as the elasticity of vapour; again look for 65° on C, and opposite to it we shall find on D 62·1, which is the temperature of the dew-point.

These two numbers having been written down we pass to the second slide. Set the point 1·0 on H to 70° (the temperature of the air) on I; the dew-point we have found to be 62°·1; find this on I, and opposite to it we find on H ·770 as the degree of humidity.

Again:—The depression of the dew-point below the temperature of the air is 8°; set *g* to 8° on G, find 62°·1 on E, and opposite to it on F we find 6·15 grains as the weight of water in a cubic foot of air at the time of the observation.

It should be mentioned that the standard scales furnished to Mr. Adie of London, the maker of the instrument, were divided at Kew by myself, with the aid of a dividing engine constructed by M. Perreaux of Paris.

CHEMISTRY.

On the Products of the Action of Heat on Animal Substances. *By* T. Anderson, *M.D.*

Dr. Anderson, having discovered picoline in coal-tar, was led to investigate the well-known and peculiar fœtid oil called bone-oil, and, to obtain the best results, operated in the last experiment upon 250 gallons of the distilled bone-oil, and discovered at least three different series of bases in the oil. In the first he had established the existence of the bodies called methylamine, ethylamine, butylamine, petinine, and probably others; in the second series, picoline, and other bodies of which it is the type. The third series is very remarkable, and all the members of it are characterized by decomposing by heat and excess of acid into bases of the picoline series, and a remarkable and peculiar red or orange-coloured resinous substance. This extensive investigation was not yet concluded; but the oil, besides these bases, contained benzole and the nitriles of some of the fatty acids.

On a Diamond Slab supposed to have been cut from the Koh-i-Noor. *By* Dr. Beke.

In the year 1832, the Persian army, under Abbas Meerza, hereditary prince of Persia, undertook the subjugation of Khorassan, which province, though nominally forming a portion of the Persian empire, had been virtually independent since the death of the great Nadir Shah, in the year 1747. The success of the campaign was complete. The important fortresses of Ameerabad and Coochan were besieged and taken, and the other strongholds of the Toorkomans destroyed; and the Persian sway was entirely re-established.

At the capture of Coochan, there was found among the jewels of the Harem of Reeza Kooli Khan, the chief of that place, a large diamond slab, supposed to have been cut from one side of the Koh-i-Noor, the great Indian diamond now in the possession of Her Majesty. It weighed about 130 carats, showed the marks of cutting on the flat and largest side, and appeared to correspond in size with the Koh-i-Noor.

The only particulars that could be obtained respecting the past history of this stone were, that it had been taken from a poor man, a native of Khorassan, in whose family it had served for striking light against a steel, in the place of a flint; and one side of it was, in fact, a good deal worn by constant use. The diamond was presented by Abbas Meerza to his father, Futteh Ali Shah, and is presumed to be now among the crown jewels of Persia. The Armenian jewellers of Tehraun asked the sum of 20,000 tomauns (16,000*l.* sterling) for cutting it; but the Shah was not inclined to incur this expense.

The foregoing particulars were furnished to Dr. Beke by his brother Mr. William G. Beke, late Colonel of Engineers in the Persian service, who took part in the Khorassan campaign.

On the Cause which maintains Bodies in the spheroidal state beyond the sphere of Physico-chemical Activity. *By* M. Boutigny.

The author referred to his former and well-known experiments on the peculiar state induced in liquids when in contact with any hot metals, and regretted he had not the means for exhibiting the experiments, as they required apparatus he had not at command in the Section, such as for the application of the spheroidal state of water to the purposes of the steam-engine. He referred to the experiments first shown at Cambridge, and their extension since, to explain some of the effects of ancient oracles. Alluding to the disputed points in the explanation of his experiments as to the repulsion of metals and fluids, and whether the effects were really entirely or not to be attributed to the properties of the thin stratum of vapour, Prof. Boutigny proceeded to show by experiment that when platina wire was coiled up in the form of a flat spiral and made hot, and æther or alcohol fluid placed on it in the spheroidal state, the liquid would not pass through between the spaces, while the vapour readily did so*.

On the Dangers of the Mercurial Vapours in the Daguerreotype Process, and the means to obviate the same. *By* A. Claudet.

In practice it is found that in that process where heat and mercury are required to bring out the image, so much vapour of mercury was produced as seriously to affect the health of the operators. M. Claudet described the means of protection.—The mercury apparatus is enclosed in a closet of iron placed outside the room through the wall, and having two sliding glass shutters communicating with the room. These shutters being constantly kept shut, and the iron closet being supplied with pipes at the top, and with two large iron shutters placed one on each side, all the vapours of mercury are immediately carried out or condensed. The mercury box is placed on a water-bath, heated by a gas burner. The supply of water to the boiler and of gas

* The members of the Chemical Section had the opportunity of seeing M. Boutigny pass his hand through a stream of liquid red-hot iron as it passed from the furnace at the works of Messrs. Ransome and May, and afterwards scooping out portions of iron from the casting ladle, until the fluid sunk to the mere red-hot fluid state, when danger might be apprehended from the falling of the temperature causing the iron to adhere.

to the burner is regulated by two pipes, the cocks of which can be opened and shut from the room as well as the two outside shutters, without opening the sliding windows in front. When the operator has to put the plates in the mercury box or to take them out, he has only to stop the external light by shutting the two outside iron shutters and to open the inside glass shutters. The iron closet is then perfectly free from mercurial vapour, and during the short time necessary for placing and removing the plates no vapour can escape in the room.

On the Use af a Polygon to ascertain the Intensity of the Light at different angles in the Photographic Room. By A. Claudet.

This was of white-coloured wood; and enabled the operator to ascertain by the appearance of the different facets when Daguerreotyped, the strength of light and shade from different parts of the room, and so to place the sitter in the best positions, and regulate the light with shades and screens, according to the effect produced on the facets.

On Agricultural Chemistry, especially in relation to the Mineral Theory of Baron Liebig. *By* J. B. Lawes *and* Dr. J. H. Gilbert.

Mr. Pusey had, in a recent article in the Journal of the Royal Agricultural Society of England, on the progress of agriculture during the last eight years, quoted the experiments of Mr. Lawes and Dr. Gilbert as being conclusive against the "Mineral Theory" of Baron Liebig, which asserts that the crops on the farm rise and fall according to the supply within the soil of the mineral constituents indicated by an analysis of the ashes of the plant. To these observations of Mr. Pusey, Baron Liebig had replied at some length in the new edition of his 'Letters on Chemistry', just published, and in doing so, has asserted that the experiments alluded to are entirely devoid of value, as the foundation for general conclusions, and that the statements of the authors could only be made in ignorance of the rationale of agricultural practices on the large scale.

The authors have therefore given in the present paper an outline of their investigations in agricultural chemistry, comprising an extensive series of experiments in the field on the growth of the principal crops, entering into a rotation; upon the chemistry of the feeding of animals; and upon that of the functional actions of plants generally, in relation to the soil and atmosphere. And in connexion with all these branches much laboratory labour has constantly been in progress since the commencement of the experiments themselves in 1843. The results selected by Mr. Lawes and Dr. Gilbert in justification and illustration of their views, were those of the field experiments on wheat; which had been grown *continuously* on a previously exhausted soil for the last eight years, and in each season, by means of many chemical manures by the side always of one or more plots unmanured, and one manured continuously by farm-yard manure. Some of the results thus obtained were illustrated by a diagram, from which it appeared that *mineral manures* had scarcely increased the produce at all when used alone; whilst the effects of ammoniacal salts were very marked, even when repeated year after year on the same space of ground from which the entire crop (corn and straw) had been removed. Indeed, in this way a produce had been obtained even in the sixth and seventh successive years of the experiment, exceeding by nearly two-thirds that from the unmanured plot. It was thus shown, that the *mineral* constituents of the soil continued to be in excess, *relatively* to the nitrogen available for them from natural sources. The history of several plots was then traced down to the last harvest (1850), and it was argued that the statement assailed by Liebig, viz. that ammonia was especially adapted as a manure for wheat, was fully borne out when speaking of agriculture as generally practised in Great Britain; in other words, that in *practice* it was the defect of *nitrogen* rather than of the *mineral* constituents that fixed the limit to our produce of corn.

The authors next called attention to the fact of the exhalation of nitrogen by growing plants, as proved by the experiments of De Saussure, Daubeny and Draper, and they referred to some experiments of their own, with the view of showing the probability that there is more of the nitrogen derived from manure given off during the growth of cereal grains, than of leguminous and other crops; and hence might be explained the great demand for nitrogenous manures observed in the growth of grain. The

authors suggested that here was an important field of study, and that we have in the facts alluded to, much that should lead us to suppose, that the success of a rotation of crops depends on the degree in which the restoration of the balance of the *organic* constituents of crops was attained by its means rather than on that of their *mineral* constituents according to the theory of Liebig; whilst the means adopted to secure the former were always attended with a sufficient supply of the latter. Again, Professor Liebig had quoted the processes of fallowing and liming, as being in their known results inconsistent with the views of Mr. Lawes and Dr. Gilbert; but these gentlemen considered that the experiments of Mulder, and especially of Mr. Way on the properties of soils, justified them in supposing that the process of fallowing and even that of liming also owed its efficacy, more to the accumulation of *nitrogen in the soil* from natural sources, than to that of available mineral constituents: the latter did, however, undoubtedly thus accumulate by these processes, and this fact should give more confidence in views, which on independent evidence supposed, that they were not so easily liable to be found in defect in relation to other necessary supplies.

It was next shown, by reference to what happens in actual practice, as generally followed in Great Britain, that where corn and meat constitute almost the exclusive exports of the farm, the mineral constituents of the crops, taken collectively, that is, as shown by the analysis of their ashes, could not be considered as exhausted. Indeed Baron Liebig himself states that farm-yard manure was the universal food of plants. And the authors would draw attention to the fact, that the practice of agriculture here supposed necessitated the production of this manure, by means of which it was that so large a proportion of the mineral elements of the crops raised upon the land were, in due time, restored to it. All our calculations therefore should be made on a full consideration of what was involved in the use of farm-yard manure. This was however not generally sufficiently borne in mind by chemists unconnected with practical agriculture; and to this cause might in great part be attributed the reiterated recommendations to imitate in artificial manures the composition of the ashes of the plants to be grown. Of the mineral constituents however, phosphoric acid would be lost to the farm (by the sales of corn and meat) in much larger proportion than the alkalies, whilst the latter would generally, by the combined agencies of disintegration of the native soil and import in cattle food, be liable to diminution in but a very insignificant degree, if not in some cases to accumulation. Practical agriculture had, indeed, decided that phosphoric acid must in most cases be returned to the land from sources external to the farm itself, viz. by bones, guano or other means; while, on the other hand, artificial alkaline manures had generally been found to fail in effect.

Indeed, taking into careful consideration the tendency of all experience in practical agriculture, as well as the collective results of a most laborious experimental investigation of the subject, both in the field and in the laboratory, it was the deliberate opinion of the authors that the analysis of the crop was no *direct* guide whatever as to the nature of the manure required to be provided in the ordinary course of agriculture, from sources *extraneous to the home manures of the farm*, that is to say, by artificial manures.

In conclusion, then, if the theory of Baron Liebig simply implied that the growing plant must have within its reach a sufficiency of the mineral constituents of which it is to be built up, the authors fully and entirely assented to so evident a truism: but if, on the other hand, he would have it understood, that, in the ordinary course of agriculture in Great Britain, it is of the mineral constituents as would be *collectively* found in the ashes of the exported produce that our soils became deficient, relatively to other constituents, they did not hesitate to say that every fact with which they were acquainted in relation to this point was unfavourable to such a view. On the contrary, they believed that nitrogen was the constituent most exhausted relatively to other constituents; at any rate, it was certain that for *wheat*, of all our crops, no supply of minerals, phosphates, &c. to the fields of Great Britain, would enable it to "obtain a sufficient supply of ammonia from the atmosphere;" and indeed, that any increased produce of it, such as British agriculture (itself so artificial) demands, could not be obtained independently of an artificial accumulation of nitrogen *within the soil.* If, however, a *cheap* source of ammonia were at command, the available mineral constituents might in their turn become exhausted by its excessive use. Of those crops of rotation, on the other hand, where the effect of mineral manures *was* characteristically to increase the assimilation of nitrogen from atmospheric sources, and by virtue of which property they indeed become subservient to the increased growth of grain, the apparent demand for those substances, was not only generally, not such *in kind,*

as would be indicated by an analysis of their ashes, but it was frequently much greater *as to quantity*, than could be accounted for by any idea of merely supplying what was to become an actual constituent of the crop.

If then we would attain by the aid of science a rational system of agriculture, the actual facts of the art itself,—the indications of direct experiments in the field,—and the study of the functional actions of plants and animals, must each receive a due share of our attention. In fact, chemistry *alone* would do little for practical agriculture.

On Liquid Diffusion. By Professor THOMAS GRAHAM, *M.A., F.R.S.,*

Professor Graham gave a view of some of the unpublished results, to ascertain whether solutions of saline bodies had a power of diffusion among liquids, especially water. The apparatus may be stated to be a bottle with ground edges, to be filled with a weak solution of the saline matter (and closed by a plate of glass), and placed at the bottom of a glass vessel of water, care being taken to keep the temperature constant. Then, taking a salt of double base, such as the tartrate of potassa and soda, if it had the power of diffusing itself in the water around, he was enabled, by converting these bases into chlorides, to ascertain if their diffusion was unequal, or a decomposition might be effected, as the manner of solution of some substances is known to cause this kind of unequal decomposition. Taking common salt as a diffusate, and ascertaining the quantity of chlor-silver to be obtained after a given time, he added one per cent. of the acids sulphuric, muriatic, nitric, oxalic, and thus ascertained how far these facilitated the diffusion of the substance or the decomposition of it; thus chloride of sodium alone yielded 7·65 of muriatic acid; but add one per cent. of nitric acid, and 10·99 could be obtained under the same conditions, and proving the decomposition of the salt. To forward the analysis of bodies in complicated mixtures, and to elucidate physiological views, he had experimented with the weaker acids, tartaric and oxalic acids, and as muriatic acid was found free in the human stomach, he had tried lactic acid; but evaporated by heat lactic acid does not decompose common salt; by the aid of this new form lactic acid is seen to possess the power in aqueous solutions.

Prof. Graham states, the obvious objections to the plan of usefully employing the diffusive power of bodies arose from the time required, and the difficulty in ordinary methods of avoiding alterations of heat; as temperature increased, it shortened the number of hours, and he employed the water-bath at steady temperatures and periods of seventy-two hours to determine the results. Common salt, having a certain diffusion at 50°, had this doubled at 110°, increasing equally for each 50° to 160° and 240°, when a quantity of four times the muriatic acid was obtained to that, at the temperature of 50°.

On some Theoretical and Practical Methods of determining the Calorific Efficiencies of Coals. By Prof. W. R. JOHNSON, *of Washington, U.S.*

Several series of experiments have been made for the purpose of ascertaining the relative values of coals :—

First, the series performed by the writer of these remarks in the year 1843, and published in 1844 at Washington; second, that of Sir H. T. De la Beche and Dr. Lyon Playfair of London, prosecuted in 1845, 1846 and 1847, and published in 1848; third, that of the same experiment published in 1849; and fourth, the series detailed in their final report of the present year. The first of the series embraces direct trials of evaporative power of forty varieties of coal, the second of twenty-seven, the third of thirty-eight, and the fourth of forty-three; hence we have the means of comparing the practical evaporative power with the results of analysis in the case of one hundred and forty-seven different samples of coal, varying in their composition from the hardest anthracites, through the softer varieties of the same, and through semi-bituminous coals, to those of the most highly bituminous class. We have also in the series coals varying much in the amount of their earthy or incombustible ingredients, as well as in that of their sulphur, water and ammoniacal compounds.

It may be proper to examine whether we have yet attained to any law of relation between the actual and the computed heating powers, or whether it be still necessary to have recourse to the steam-boiler itself to determine the efficiency of any new variety of coals. The Commissioners at London have expressed the opinion that the element *hydrogen* exercises in the case of the Newcastle coals " a very essential import-

ance in their heating powers, and must not be neglected in comparing the analytical with the economic results." How this conclusion is to be justified from the data afforded, either by the comparison of Newcastle coals among themselves, or by a comparison of them with the coals of Wales with which those of Newcastle are supposed to compare the more favourably, in consideration of their containing a higher per-centage of hydrogen, it seems not easy to conceive. In fact, whether we compare the *eighteen* Newcastle coals among themselves, or the *thirty-six* Welsh coals among themselves, or whether we compare the whole of the Welsh with the whole of the Newcastle series, we find that the higher evaporative efficiency is in neither case indicated by a higher per-centage of the hydrogen element.

The first nine of the Newcastle coals (Table 3, p. 5, 3rd Report) have an average evaporative power of 8·63; the last nine have 7·38; while the average hydrogen of the two sets of nine is in each case precisely the same, namely, 5·31 per cent.

It therefore appears that the hydrogen element could have exercised no influence on the relative heating powers of the two halves of the Newcastle series. But the carbon element in the first half of the series is greater than in the last half, in the proportion of 82·69 to 81·35.

The first eighteen of the Welsh series gave an average evaporative power of 9·74, and the second eighteen an average of 8·50; the average per-centage of hydrogen in the first eighteen being 4·64, and in the second eighteen 4·97; in other words, the lower heating power belongs in this case to those coals which have the greater proportion of hydrogen. If "the hydrogen has exercised a very essential importance," it has certainly done it by *diminishing*, not by *augmenting*, the evaporative power. How stands the case when we compare the *carbon* element with the evaporative power? The first eighteen give carbon 87·14 and the second 80·71. Arranging the sets in the order of evaporative powers, we have—

	Steam.	Per cent. of Carbon.	Per cent. of Hydrogen.
First *eighteen* Welsh coals...	9·74	87·18	4·64
Second *eighteen* Welsh coals	8·50	80·71	4·97
First *nine* Newcastle coals...	8·63	82·69	5·31
Second *nine* Newcastle coals	7·38	81·35	5·31

If, instead of the mode of comparison just given, we take the three entire series of British experiments as presented in the three reports respectively, and select from each the six highest results in evaporative power, and also the six lowest, and then compare those results with the respective per-centages of carbon and of hydrogen, we have the following averages:—

	lb.	Carbon per cent.	Hydrogen per cent.
Of the first series, the six highest gave steam to 1 of coal	10·59	84·89	4·42
Of the first series the six lowest	7·72	77·72	5·26
Of the second series the six highest...	10·51	88·65	4·29
Of the second series the six lowest ...	7·14	78·44	5·33
Of the third series the six highest ...	9·90	85·92	4·65
Of the third series the six lowest......	7·09	77·11	4·94

In the American series it had been shown, by comparing the results of ultimate analysis on six varieties of coal with the calorific power expended both on the water of the boiler, and on the gaseous and vaporous products of combustion, that, in those cases at least, there was a perfect correspondence of the total heating power with the total carbon constituent of the coal.

Some comparison may now be made to show how far the steam-generating power of the coals may be inferred from their lead-reducing power, when burned in contact with litharge according to the method of Berthier. As all the American coals tried in 1843, as well as all the British coals since tried, were tested in this way, we have for the purpose of this comparison fourfold series of results embracing about 147 samples of coals. Taking the six highest and the six lowest evaporative results of each

series as before, the following numbers on which the comparison may be made are obtained:—

		Weights of Steam.	Weights of Lead reduced.
1. The American series of 1844	highest six	10·18	30·03
	lowest ditto	7·55	25·76
2. The first British series, 1848	highest six	10·59	31·0
	lowest ditto	7·72	26·7
3. The second British series, 1849	highest six	10·51	33·7
	lowest ditto	7·14	26·2
4. The third British series, 1851	highest six	9·90	32·16
	lowest ditto	7·09	27·1

Assuming, for the purpose of comparison, that the highest evaporative power in each of the four series was truly represented by the lead-reducing power of the same coals, and supposing that the evaporative powers of the six lowest of the series were to be *calculated* from their reductive powers, we should obtain the following proportions:—

1. The American series 30·03 : 10·18 : : 25·76 : 8·73
   (= calculated steam power).................................... 7·55
2. The first British ditto 31·0 : 10·59 : : 26·7 : 9·12
   (= calculated steam power).................................... 9·72
3. Second ditto, 33·7 : 10·51 : : 26·2 : 8·88
   (= calculated steam power).................................... 7·14
4. Third ditto, 32·1 : 9·90 : : 27·1 : 8·24
   (= calculated steam power).................................... 7·09

Hence it appears that in attempting to compute the evaporative power of coals which gave the lowest results from their lead-reducing power, as compared with that of coals giving the highest evaporative action, we obtain in every one of the four cases numbers largely exceeding the practical results from the steam-boiler:—

	Calculated.		Experimental.		Diff.			
The first comparison gives...	8·73	—	7·55	=	1·13	=	15·3	per cent. excess above the experimental result.
The second comparison gives	9·12	—	7·72	=	1·40	=	18·2	
The third comparison gives	8·88	—	7·14	=	1·74	=	24·3	
The fourth comparison gives	8·24	—	7·09	=	1·15	=	16·0	

From this it should seem that in applying Berthier's test as a standard of comparison, we are liable to over-estimate the evaporative power of the coals of high bituminousness (containing much hydrogen), and that the excess may, in extreme cases, amount to from 16 to 24 per cent. of their practical efficiency. It is not, however, to be inferred that the series of analyses by this method is without practical value. Having so wide a range in the constitution of coals with corresponding reductive and evaporative powers already determined, we may readily intercalate any new variety of coal analysed and tested by litharge, and thence deduce its approximate evaporative power, subject, of course, only to that degree of uncertainty which results from a want of perfect conformity in constituent elements with the coals placed nearest to it in the order of reductive powers. When both proximate and ultimate analyses show a good degree of coincidence with any coal already tested under the steam-boiler, and the lead-reducing power of the new variety also corresponds nearly with the mean of those above and below it in the scale, there seems to be little doubt that its evaporative power will also form a corresponding term in the series of calorific efficiencies.

It is generally known that several chemists have proposed the *fixed carbon* of coals, or that remaining in their cokes, as a standard by which to estimate their evaporative powers. This method is subject to the objection that the weight of coke itself, and consequently the weight of its fixed carbon, is liable to vary within certain limits, with the rate of distillation, that is, with the rapidity of the coking process. In many highly bituminous coals the sudden application of an intense heat will expel, in the

form of volatile matter, from 2 to 4 or 5 per cent. more of the weight of coal than a moderate or slow application of heat would do.

The four series of experiments afford the following comparison between the highest and the lowest six results in heating power, as related to the fixed carbon in the several coals:—

	Fixed Carbon per cent. of highest six.	Fixed Carbon per cent. of lowest six.	Steam of highest six.	Steam of lowest six.	
				A. By experiment.	B. By calculation.
American series...	79·96	56·86	10·18	7·55	7·24
1st British	74·94	50·73	10·59	7·72	7·16
2nd British	81·62	51·80	10·51	7·14	6·67
3rd British.........	73·16	50·04	9·90	7·08	6·77

It is here evident that calculation gives in every case a lower result than experiment; indicating that coals of a highly bituminous nature will be under-estimated in comparison with coals of low bituminousness, and that the amount of this undervaluing is 4·1 per cent. for the first, 7·2 for the second, 6·5 for the third, and 4·5 for the fourth series, and, on an average of the whole, 5·5 per cent. of the entire power of those weaker coals.

As coals of high bituminousness yield up, together with their hydrogen, a considerable quantity of their carbon while undergoing the coking process, it is apparent from the experiments that the steam-generating power of such coals is dependent, in a small degree at least, upon the volatile product of their distillation; but, as it has already been shown that the hydrogen element is not that on which coals depend for this power, we are led to infer that it is the volatilizable part of the carbon which in such coals makes up for the calculated deficiency of the fixed carbon.

Reference has already been made to some experiments which seem to demonstrate that the total calorific or evaporative efficiency of coals, as proved by direct evaporation and by reducing the heat expended on the products of combustion to its equivalent evaporative power, is proportional to the total amount of carbon.

It must be evident that either in a sensible or in a latent state a very large amount of caloric must pass from a furnace to its chimney. By an examination of the temperature and composition of the gaseous and vaporous mixtures sent into the chimney during the combustion of different varieties of coals, our experiments in America proved that, while the anthracites seldom expended more than $12\frac{1}{2}$ per cent. of their whole heating power on the products of their combustion, the highly bituminous class expended 18, 20, and sometimes as high as 24 per cent. in the same way. It may consequently happen that when, as in the British experiments, we compare the carbon element with the evaporative power expended on the boiler alone, the calculated will exceed the experimental result in the highly bituminous coals. The highest and lowest sets already compared give the following average per-centage of carbon, viz.—

	Carbon, highest six.		Carbon, lowest six.		Steam, highest six.		Steam calculated for lowest six.	Steam by experiment, lowest six.
First series......	34·89	:	77·72	: :	10·59	:	9·65	7·72
Second series...	88·65	:	78·44	: :	10·51	:	9·30	7·14
Third series ...	84·92	:	77·11	: :	9·90	:	8·98	7·09

Compared with the fixed carbon these figures show that the coals of highest evaporative power lost by coking 11–13 per cent. of their carbon, and those of lowest evaporative power 34·6 per cent. They also show that the calculated exceeds the experimental result in every one of the three cases; and that the average excess is 27·3 per cent. of the experimental evaporative power, reckoned from the quantity of steam expelled from the boiler.

From this statement it follows that computations founded on the per-centage of fixed carbon will give nearer approximations to the practical action of coal in evaporating water from a steam-boiler than either of the other methods; and that the error will seldom exceed 5 or 6 per cent. It does not, however, follow that the direct manner of ascertaining the economic values of coals can be dispensed with. So many questions besides that of the bare evaporative power merit attention in selecting coals

for various purposes, that it will, I conceive, be still desirable to appeal to the steam-boiler and the other experimental appliances whenever a new variety of coal offers itself for adoption in the market.

On a new Method of contracting the Fibres of Calico, and of obtaining on the Calico thus prepared Colours of much brilliancy. By Mr. MERCER. (*Communicated by* Dr. LYON PLAYFAIR, *F.R.S.*)

Dr. Lyon Playfair, who delivered the notice of this subject, said that Mr. Mercer had his attention drawn to the subject by experiments made as early as 1844. Dr. Playfair briefly called attention to the states of water, the points of maximum density so well known, and the experiments of Mr. Mercer, who found that above this point water flowed more rapidly through a syphon than at the same number of degrees below this point of maximum density. He then spoke of the theoretical views of those chemists who look upon the combined water as in the state of ice, or free from fluidity. Mr. Mercer's discovery may be stated in few words to be this:—a solution of cold but caustic soda acts peculiarly upon cotton-fibre, immediately causing it to contract; and although the soda can be readily washed out, yet the fibre has undergone a change, and water will take its place and unite with the fibre. In a practical view Mr. Mercer considered that the fibre might be considered by this action to have a sort of acid property to unite with soda and then with other bases. The effect of the condensation was said to be one-fifth to one-third of the total volume of cotton employed. Dr. Playfair then showed some proofs of the influence of this new process upon our cotton manufactures; thus, taking a coarse cotton fabric and acting upon it by the proper solution of caustic soda, this could be made much finer in appearance; and if the finest calico made in England, known as 180 picks to the web, was thus acted upon, it immediately appeared as fine as 260 picks. Stockings of open weaving were shown, and the condensation process made them appear as of much finer texture. The effect of this alteration of texture was most strikingly shown by colours. The pink cotton velvet had its tint deepened to an intense degree by the condensation process. Printed calico, especially with colours hitherto applied with little satisfaction, as lilac, had strength and brilliancy, besides thus producing fabrics cheaply finer than can possibly be woven by hand. The effect was shown of patterns being formed by portions of a surface being protected by gum from condensation. Thus patterns of apparently fine work can easily be produced. It was stated that the fabrics by this process have much strength given them; for a string of calico one-half condensed by caustic soda will break by 20 oz., while the unacted upon string of cotton broke with 13 oz.

On the Action of Superheated Steam upon Organic Bodies. By Professor E. A. SCHARLING, *of Copenhagen.*

This communication was read by Dr. T. Anderson, who exhibited a drawing of apparatus employed.

On Gambogic Acid and the Gambogiates, and their use in Artistic Painting. By Dr. SCOFFERN.

The author described gamboge as a gum-resin, and stated that some years since he had proposed the use of a preparation of it for oil-painting. For this purpose he had employed methods to get rid of the gum. To obtain the gambogic acid, he recommended ether to be employed; the colouring matter is dissolved, and by distillation the ether is given off; the last portions, however, are retained with so much force that a temperature of 230° or 240° is obtained, and this would destroy the colour, unless water was employed with the ether. About one-twentieth of water was previously added to the etherial solution of the pigment, or gambogic acid. The gambogiates of lime and other bases were under examination; the gambogiate of iron, however, produced a rich brown, like asphaltum, but capable of more richness and certainty in oil:—from the trials made, the yellow and brown seemed to be permanent colours, having useful properties as oil-colours. Dr. Scoffern also thought they might be usefully employed in fresco.

On Sulphuric Acid in the Air and Water of Towns. *By* Dr. R. Angus Smith.

The experiments and observations were generally directed to the existence and quantity of sulphuric acid in the atmosphere of large towns, and from the examples taken in and near Manchester. Dr. Smith, admitting that sulphurous acid was first produced by combustion, considered it was oxidized and carried down by rain as sulphuric acid, and usually associated with ammonia. Liebig had proved carbonate of ammonia to be present in the air. Dr. Smith found that rain-water was alkaline until boiling concentrated the sulphuric acid. Rain-water collected six miles from Manchester was such that it could not be used agreeably for drinking. He considers the soil as a great disinfectant of the rain-waters,—removing the acids, the ammonia, and the oily and carbonaceous matters that give unpleasant qualities to rain-water. Rain collected even in the fields on concentration had so much oily matter developed by evaporation, that suspicion of accidental impurity from the vessels employed was only removed by the employment of platina vessels. Specimens of air taken in the summers of 1850 and 1851 from the densest parts of Manchester were compared with air from the country. The quantity of sulphuric acid, estimated in tabular form, ranged from 0·4 to 1·06 grains to the gallon; the chlorine was from 0·396 to 0·530 to the gallon, while the total quantity of inorganic matter in rain-water was from 0·8 to 3 grains to the gallon. Dr. Smith alluded to the growth of conferva, and the production of some living bodies, and made observations on the office of rain-water thus clearing the air of matters affecting the health of man.

On Solid and Liquid Camphor from the Dryobalanops Camphora. *By* Professor J. E. De Vry.

Dr. De Vry gave the history of the rarer species of camphor from Sumatra and Borneo, the price of which is thirty to forty times greater than that to be met with in commerce, and after quoting from the work 'De Kamferboom van Sumatra' of W. H. de Vriese of Leyden, and the opinions of Berzelius and Pelouze as to the composition, gave his experiments, which led to his opinion that the fluid camphor or oil of camphor was rather to be regarded as a balsam than as an oil, and that the whole subject of the camphors deserved attention to clear up the obscurity of their history.

On Nitro-Glycerine and the Products of its Decomposition. *By* Professor J. E. De Vry.

This yellow liquid, nitro-glycerine, seems not to be poisonous, but it explodes at a moderate heat, as was shown by experiment, detonating when the drops of nitro-glycerine on paper were struck a smart blow with a hammer.

On the Construction and Principles of M. Pulvermacher's *Patent Portable Hydro-Electric Chain Battery and some of its Effects.* *By* W. H. Walenn.

The galvanic battery now presented to the notice of the Section is the invention of M. Pulvermacher of Vienna, and was originally intended by him to supersede the electric apparatus sometimes used, and advised by physicians to be worn on the body for the relief or cure of certain diseases to which the mild but continuous influence of galvanism is of service.

The chief objection to the instruments hitherto employed for these purposes is, that consisting only of a single pair excited by the exhalating cuticle, there is a want of sufficient intensity, and consequently the amount of electricity brought into action by means of them is so exceedingly small as not even to come under the denomination "mild." This serious objection has been entirely, and, as will be seen, satisfactorily obviated by M. Pulvermacher, the chain-batteries being so constructed that each link is a single hydro-electric element; and the links are connected on the principle on which galvanic pairs are connected in general for intensity of action, thus giving a much more copious and effective galvanic current than that obtainable from the apparatus above alluded to. The details of its construction are as follows:—

In order to produce a large surface within a small space, and with little material, positive and negative wires are coiled round a small lengthy piece of wood in such a manner that they run parallel to each other at very small distances but without intermediate contact. At each extremity of the wooden core the end of one of the wires is bent into a gilt eye (the other end being fixed in the wood), so that at one extremity of the wood, the eye from the positive wire at the other extremity, that from the negative wire projects beyond the core; the whole forming the metallic part of a galvanic element, with space between the wires for the fluid. A number of such elements linked together on the principle of the voltaic pile, therefore, constitutes the metallic part and arrangement of a battery, *permanently connected, flexible in all directions, of considerable surface* (quantity), in proportion to its size, and of an intensity *only limited by the number of elements employed.*

When this chain is immersed for a moment into any dilute acid, the capillary attraction between the parallel wires and the absorption of the wooden core, on the removal of the chain from the liquid, retains a quantity of fluid sufficient to excite the battery from one to two hours. To account for the surprising power and constancy of these small batteries, it must be considered—

First. That the acting surface is very considerable in proportion to the substance of the metal, the wires being excited on the whole of their surface.

Secondly. That the resistance of the fluid to conduction of the electric current is reduced to a minimum, the layer of fluid between all parts of the wires being very thin.

Thirdly. That no adherence of gas to the negative wire takes place, owing to the facility afforded for its escape by the thinness of the layer of fluid interposed; for the same reason the counter polarization of the negative plate by the deposition of metallic zinc upon it (which is a necessary consequence of the action of any other single fluid circle) is effectually prevented.

For experiments in which an intermitting current is required, M. Pulvermacher has contrived two instruments :—

First. The interrupting cylinder, consisting of a spiral spring fixed in a small glass tube so as to produce by every motion of the instrument an intermittent connexion between two metallic hooks at the extremities of the tube; this is principally used for physiological and medical effects, as the shock given to a person holding the chain communicates constant and continuous vibration to the instrument sufficient to produce the requisite intermission in the connexion.

Second. The portable interrupting clock-work (size five cubic inches), by which the current is made more rapidly and regularly intermittent.

The following are some of the properties and uses noticeable in this form of battery:— A galvanic battery of 120 elements, permanently connected and therefore ready for instantaneous use, only occupies the space of an ordinary pocket-book. In the laboratory it will form, no doubt, a very useful instrument of research, when it is borne in mind that the ready, and, in some cases, instantaneous application of electricity (even were it attained only with instruments of small power) is one of the greatest desiderata of the present day and in the present state of science ; the general usefulness of this instrnment will then immediately become apparent.

With the application of it to these ends then only in view, the following points of interest present themselves, viz. that it is a good and instantaneous means of testing solutions in which either acids or bases are suspected to exist in small quantities; that it affords a ready and almost instantaneous means of coating metallic and other conducting surfaces with thin films of metals, either in the most minute state of division, in a crystalline manner, or in a reguline form; that as the intensity of this arrangement may be said to be unlimited, it decomposes the oils and hydrocarbons with facility, thus opening a wide field of research.

Eight elements charged with distilled water decompose distilled water, and other most unequivocal proofs of enormous power in this respect are given : it is also capable of giving all the results of common statical electricity, still combining the admirable continuity of action of an hydro-electric arrangement, with the sharp effects of that derived from the frictional machine.

The heating effects of this arrangement will not be without their uses, both in exploding gases and other materials. It has also been suggested, that for the easy communication, by electricity, from a train on the line to any station, or at by-stations

where expensive batteries have to be constantly kept charged, although but seldom used, these batteries would be found to possess great advantages, as they would be in action, only when required, by a momentary immersion into dilute acid.

This battery likewise possesses surprising magnetic and odylic power, for its size; but these applications of it still afford ample scope for further investigation and research.

On the Constitution of Salts. *By* Professor A. W. Williamson.

Chemists have of late years considerably extended the meaning of the term salt; acids and bases are now rather viewed as acid salts and basic salts respectively, than as compounds of fundamentally different arrangement, and there seems reason to believe that the molecular structure of the so-called simple bodies is analogous to that of salts. Thus any view which best explains the properties of salts may be expected to apply ultimately to the molecular structure of matter in general.

It was remarked that a serious error had crept into chemical science by the introduction of a different unit of comparison in organic chemistry to that which is employed in the inorganic department of the science. The removal of this error and adoption of an uniform standard of comparison, naturally leads to viewing chemical action as consisting in substitutions rather than in direct combinations. The best studied processes of organic chemistry have been found to consist of double decompositions. Numerous other instances were mentioned, in which the result may be far more simply explained by a process of double decomposition than by the supposition of unknown predisposing affinities invented for each; and various arguments were adduced why the same mode of reasoning ought to be extended even to the simplest phænomena of inorganic action generally considered as mere combinations or separations. It was shown that water may be assumed as a very general if not universal type and standard of comparison, by viewing other bodies as formed from it by the replacement of one or more atoms of hydrogen in water by their equivalent of various simple or compound radicals. The atom of radical thus replacing hydrogen is sometimes equivalent to one atom of that element; in other cases it is equivalent to two. The difference between monobasic acids, such as nitric and bibasic acids as sulphuric, were shown to follow as a necessary consequence of such a difference of the respective radicals NO_2 and SO_2.

GEOLOGY AND PHYSICAL GEOGRAPHY.

On the probable Dimensions of the great Shark (Carcharias megalodon) *of the Red Crag.* *By* J. S. Bowerbank. *F.R.S.*

The teeth of this fish are common in the coprolite beds of Suffolk; but although exceedingly hard, they are usually much water-worn, and have nearly always lost the serrated edges which are so well preserved in specimens of the same species from Malta. The teeth of the upper jaw may be known from the lower teeth by their comparative narrowness and thickness; those from the sides of the jaws are progressively smaller and shorter. The largest specimens measure from $4\frac{1}{2}$ to 5 inches in length. In order to give some idea of the magnitude of the creature to which they belonged, Mr. Bowerbank exhibited the jaws of the largest known specimen of the *Carcharias glaucus* of Australia; it was killed by a whaling crew, at Port Fairy, Australia. It measured 37 feet in length; its vertical gape is $25\frac{1}{2}$ inches, its horizontal $20\frac{1}{2}$ inches; the length of its largest teeth $2\frac{5}{8}$ inches. From the measurements it is inferred that the fossil shark must have had a gape of at least 3 feet by 4, and an entire length of not less than 65 feet. This estimate is not at all improbable, as there exists a (comparatively harmless) species—the Basking Shark—in the British seas, of which one individual, killed off Brighton, measured 36 feet, and one which was stranded in the Orkneys, and described as a "sea-serpent," exceeded 50 feet in length. Looking at the mineral character of these fossils, and their association with the teeth of a second Maltese shark (*Oxyrrhina hastalis*), not found either in the London clay or coralline crag, Mr. Bowerbank was inclined to regard them as having been derived from the

destruction of some older deposit, perhaps an extension of the great miocene formation of southern Europe.

On the Remains of a Gigantic Bird from the London Clay of Sheppey. By J. S. Bowerbank, *F.R.S.*

The specimen described is a fragment of one of the bones of the extremities; it is 4 inches long and 1 inch in diameter at the larger end, and is somewhat three-sided, with rounded angles. The thickness of its walls is from $\frac{3}{4}$ of a line to $1\frac{3}{4}$ line; its microscopic structure exhibits the characteristic bone-cells of animals of the bird tribe. The specimen indicates the bird to have been at least the size of a full-grown Albatros.

On the Pterodactyles of the Chalk Formation. By J. S. Bowerbank, *F.R.S.*

The author exhibited drawings and restorations of remains of these winged reptiles, showing that the great species of the chalk (*P. Cuvieri*) must have had a spread of wing equal to 16 feet 6 inches; whilst a second large species (*P. compressirostris*) was estimated at 15 feet. The largest species from the lias previously well known, the *P. macronyx* of Buckland, was only computed at 4 feet 7 inches from tip to tip of its expanded wings.

Indications of Upheavals and Depressions of the Land in India. By Dr. Buist, *LL.D.* (*Communicated by* Col. Sykes.)

Referring to the well-known cases below the sea-level in Europe, Dr. Buist states that all around the shores of India, from Calcutta to Bombay, appearances exactly similar to these present themselves. In 1815, in the clearing out of the Dhurrumtollah Tank in Calcutta, the workmen at the depth of about 24 feet from the surface passed through a bed of sand and came to a group of full-grown trees; these were standing perpendicularly at short distances from each other, and had the appearance of trunks lopped off within three or four feet from the roots*. In general they were about a foot and a half in diameter; they were firmly fixed in a dark loamy soil, into which their fangs spread in every direction; their elbows, where the trunk separated into the roots, were peculiarly distinct; they were of a reddish colour, the fibre soft and moist, but still preserving unaltered the grain of the wood. The recent operations of Mr. Simms have given an exactitude to these observations they did not at the time possess. The bottom of the tank, where the roots were found, is, according to him, about 24 feet† below the surface of the ground, which, again, is about a similar distance above the lowest low-water mark at Kyd's Dock, this last being about the same level with the bottom of the tank; so that with a tide range of 16 feet the tree-roots are $8\frac{1}{2}$ feet beneath the mean level of the sea and 16 below high-water mark. In the bottom of a tank three miles distant from this exactly the same appearances were discovered, as they were in the excavation of the docks by Mr. Jones, and in the clearing out of various tanks on the other side of the river. About the year 1810, the same appearance presented itself in deepening the Laldiggee in Tank Square. At Dum Dum, eight miles further up‡, not only trunks of trees but bones and deer's horns were found at a great depth from the surface. At Bombay, again, during a violent fall of rain in 1849, a torrent near Sewree cut through a bank of shells and gravel cemented together into a kind of stone which prevails all up and down over the coast, and to which, from its appearance and position, I have given the name of Littoral Concrete. At the particular spot referred to the mass was found to be about 6 feet thick; underneath this, and about 4 feet below high-water mark, was a mass of blue clay, the same in appearance as the sludge now depositing on our shores; this varied from 1 to 3 feet in thickness, and was everywhere full of tree-roots obviously *in situ*, apparently the mangrove, which always grows betwixt high and low-water mark. The fibres were traceable everywhere through the clay, and where, by reason of their fineness they had become obliterated, casts of them still remained. In many cases the woody

* Calcutta Gazette, 1815. † Bengal Hurkaree, April 30, 1851.
‡ Calcutta Gazette, 1815.

fibre was fresh and tough, and could be cut with an axe or saw, to which it yielded with considerable difficulty. It was of a reddish colour, like that which mahogany assumes when steeped in water; in the great majority of cases it was reduced to a black, pulpy state, like charcoal or the decayed timber found on our sea shores at home. This, when exposed for a few weeks to the air, became hard and brittle, and broke with a bright resinous fracture and lustre, something like that betwixt lignite and jet. When exposed to damp, it in many cases became covered with a greenish-white efflorescence of sulphate of iron, a substance produced in such abundance in the lignite formation near Quilon that it is collected and sold as a mordant to the dyers. The tree-roots referred to were everywhere perforated with holes, the work of worms or some other borer; these varied from a quarter of an inch to an inch in diameter; they are almost invariably lined with beautiful incrustations of carbonate of lime, from the thickness of an egg-shell to that of a crown-piece; these incrustations are composed of a multitude of distinct layers, and form tubes of the most fantastic appearance, varying from a few inches to some feet in length, but so brittle that it is seldom that more than half a foot can be taken out entire. Until the present year the arrangement here described was only observable in two or three localities. In consequence of the cuttings of the railway and town drain, together with the deepening of nearly all our old wells and the excavation of numberless new ones, during the present season excellent opportunities have presented themselves of inquiring further into the matter, and the result has been that over nearly a third of the island of Bombay, or with a few exceptions, wherever the shell, gravel and concrete form the material at the surface, blue clay with mangrove roots, in all respects similar to those described, are found beneath. Captain Fulljames appears to have found nearly the same arrangement at Gogo in the Gulf of Cambay, and the same thing, so far as I can judge, is described by Capt. Vicary* as visible at Kurrachee. I have in my possession the grinders and jaw-bone of an elephant dug out of a well a little way above Kurrachee, from about 20 feet under the surface of the ground, probably from the same formation. There are in all likelihood numberless examples of the same appearances all along our coast if they were inquired after. At present we only find the mangrove growing in shallow and sheltered spots where mud is freely deposited, and we cannot expect its remains to prevail over a larger area than that at present occupied by the living plant. There seems to me no means whatever of explaining the appearance of the deposit of shells and gravel, which from their appearance are manifestly the result of quiet aqueous deposition and not of wind-drift, above tree-roots obviously *in situ*, except by the hypothesis that these latter, after having obtained their present size, sunk with the soil on which they grew beneath the level of the sea to such a depth as to permit the mass which now covers them to accumulate. From the excavations lately made on the Esplanade, Bombay, it would appear probable that the descent which gave rise to this was a sudden one. In the bottom of a well 12 feet deep, just as the rock was reached, coral such as that now prevailing on our shores was found in abundance; it was perfectly uninjured, every pore and fibre remaining as entire as when the zoophyte lived in it. The same species of coral now found on our shores never forms a rock; when it attains the size of a cubic foot or so the zoophyte dies; the coral is immediately thereafter detached from the rock, and in a short time rounded or ground to powder by the surge; the least exposure to abrasion or impact from any hard substance proves fatal to the texture of a substance so delicate. The proofs of an upheaval subsequent to the subsidence are plentiful.

It seems to me impossible to explain the production of river deltas on the usual hypothesis of a deposit of silt from running water, and that mud such as that which constitutes them is never thrown down except when the water which suspends it has been permitted to remain for a considerable period in a state of repose. By what means can it be imagined that the Deltas of the Ganges, Indus or Nile, should ever be enabled to attain a level high above the reach of the highest inundations, if the relative levels of land and water had at the time of their formation been as at present? Assume that these rivers discharged their waters into a long shallow estuary of the sea, the bottom of which afterwards became elevated by upheaval, and the whole matter is simple. At Madras, from the powder-mills to Enmore, and so for many miles up and down the coast, fragments of bone, oyster-shells, land and sea-

* London Geological Transactions.

shells and cuttle-fish bones occur along a level tract which varies from a hundred yards to twenty miles in breadth. The shells have in most cases retained their form and appearance, but in black clay soils they are changed into a clear selenite or dirty fibrous gypsum, showing crystallization of the latter substance, but retaining enough of their original form and shape to identify their origin. The greater part of the character of the Coromandel coast is similar to this. After penetrating through the sand mixed with shells, a deep bed of soft blackish clay is generally found, containing so much water that the foundations of the buildings constructed where it occurs can only be laid on the walls* used for foundations and peculiar to Madras. At Adgar, the small weir, about eight miles from Fort St. George, which forms the limit of the Supreme Court jurisdiction in that direction, large quantities of recent sea-shells are constantly being dug up for the use of the lime-burners three miles from the shore. These occurred at a depth of from 8 to 12 and 20 feet, under a stratum of red gravelly soil, the pebbles in which are mostly quartz and angular in form. The whole plain in this direction is considerably raised above the level of the sea, and presents the same geological appearances. The plain between the isolated hills of Amravutty and the sea slopes gradually towards the shore, and has the appearance of an extensive alluvial deposit, from the surface of which the subordinate hills rise like so many islands. The upper bed consists of *regur* or black cotton soil, varying from 6 inches to 20 feet in depth, with a subsoil of stiff unctuous clay, a stratum of sand or gravel occasionally intervening. Between Chandole and Chinna Ganjam, a black soil gives place to a belt of sand 8 to 10 miles in breadth, the whole bearing the appearance of an old sea beach. Along the sea-margin of Western India we find almost everywhere vast expanses of nearly level ground, from 3 to 10 feet above high-water mark, consisting exclusively of the shells and gravel such as I have already described, in a loose or cemented state, according to circumstances. When cemented, the material is used extensively as a building-stone, and the greater part of the less substantial houses in Bombay have been constructed from it. It in general abounds in fine fresh water, and forms the ground on which those magnificent cocoa-nut groves which skirt our shores prevail; they extend around the whole of the shores of the Arabian Sea as far as Soonmeani, beyond which my information is imperfect, with the exception always of the vicinage of the debouchures of our great rivers, where the Delta abuts directly on the sea. Around the peninsula of Aden, and along the shores of the Red Sea on both sides, they are peculiarly conspicuous, stretching on the African coast many miles inland. Around Suez there is a vast expanse consisting of shells and gravel, in appearance so fresh and recent, that one might imagine it to have formed the channel of the sea a few months before. Capt. Newbold describes a similar beach as prevalent along many of the shores of the Mediterranean. Returning to the East, the island of Mauritius is belted by an enormous coral reef throughout the whole shore, excepting about 10 miles; this rises from 5 to 15 feet above high-water mark, and is worn in some places into the most fantastic shapes by the surge. The Observatory of Port Louis is built upon a bed of coral 10 feet above high-water mark. Blocks of coral, too vast to be transported by any existing agency, are found from 600 to 1300 feet inland, cut off from the shore by elevated ridges; and a considerable way in the interior two remarkable headlands of coral, from 20 to 25 feet above the level of the sea, are to be met with in the jungle. The great part of the numberless coral islands which are scattered between the Cape of Good Hope and Ceylon, the Chagos Archipelago, the Seychelles, Laccadives and Maldives, appear to have been elevated to their present level by the same upheaval by which the terraces now under consideration have been produced, and I have no doubt abundance of traces of the same thing will be found all along the shores of our Eastern seas. I need not enumerate the numberless examples of old sea-margins to be found all along the shores of England and Scotland, infinitely more familiar, as they must be, to resident geologists than to an exile.

The theory of subsidence and subsequent upheaval which I have just endeavoured to establish seems alone capable of explaining the production of coral reefs. As the rock on which they rested descended, the zoophytes would naturally work their way upwards to the surface of the sea, on the approach of which their operations are invariably discontinued. An upheaval such as I have assumed would bring the surface of our Attolls to their present level, which they could by no other process have attained.

* Hollow brick cylinders.

In writing on this subject I may refer to another of almost equal interest and novelty, referring to a change in the aspect of the interior of India, not, so far as I know, hitherto described. Along the line of the Moolla and Motamoola, near Poona, where the river cuts through deep beds of alluvium, about 15 feet under the surface, a stratum of freshwater shells makes its appearance; they are sometimes loose in the clay or sand, more frequently they are cemented together by calcareous matter: they are for the most part perfectly entire and fresh, and seem, so far as I can judge, identical with those now in existence. These beds are found over a vast expanse of country, wherever, in fact, alluvium of any considerable thickness prevails. The alluvium contains hardly any gravel or stones; it lies in uniform beds, and bears every appearance of having been a lake-, none of having been a river-deposit. Dr. Gibson, Inspector of Forests, is convinced that the whole alluvium of the Deccan owes its origin to a vast series of magnificent lakes of comparatively recent existence, lakes which must have affected the climate as well as the whole character of the country. Compared to the swamps referred to by Dr. Malcolmson and Dr. Falconer*, the collections of water under consideration must have existed as of yesterday; and were the regions over which they prevail examined with sufficient care, we might be enabled to map out the area which they occupy, and infer with considerable accuracy the age to which they belonged.

On the Echinodermata of the Crag. By Professor E. Forbes, *F.R.S.*

These fossils, amounting to twenty species, are mostly obtained from the coralline crag. They consist of two new Comatulæ, not related to the existing British, but to Indian species; a unique specimen of a star-fish from the Red Crag, identical with the recent *Uraster rubens*; four Echini, of which one is the common British species, *E. sphæra*; three others allied to *Temnopleurus*,—a genus not now living in the Atlantic, but living in India, where it also occurs fossil; two species of *Echinocyamus*, one identical with the British *E. pusillus*; fragments of an *Echinoneus*, two species of Spatangus, one *S. purpureus*, the other *S. regina* (Gray), of Malta; a species of *Amphidotus*; and lastly, *Brissus Scillæ*, which occurs both living and fossil in the Mediterranean, but is properly a tropical Indian form. In this assemblage there is a mixture of Celtic with Indian types, and an absence of characteristic Lusitanian forms; as if during the crag epoch there had existed a communication with the eastern seas, but a barrier to the south,—a conclusion which would harmonize with Mr. Searles Wood's inferences from the shells of this formation.

On the Discovery by Dr. Overweg *of Devonian Rocks in North Africa. By* Professor E. Forbes, *F.R.S.*

This was an announcement of an important discovery made by Dr. Overweg in Fezzan, whence he has sent specimens of true Devonian rocks with fossils identical with those of the Devonians of the Sierra Morena in Spain. No palæozoic rocks have hitherto been discovered in Africa north of the line; and this new fact may probably prove of consequence in explaining the physical and organic peculiarities of Africa, and taken in connexion with the fact of the existence of Devonian rocks in the Cape region, may indicate a palæozoic axis running north and south through that continent.

The Rev. J. Gunn exhibited the Femur of a gigantic Fossil Elephant, dug up on the beech at Bacton. It is the shaft only, without the epiphyses, of a young animal, and measures four feet in length; by placing with it articulating extremities of corresponding size from the same formation, the complete femur is shown to have been *five feet* in length. The head of another femur, from Mr. Gunn's collection, was obviously too large to have belonged even to this magnificent specimen. Another entire femur of an aged elephant, dredged up off Yarmouth, was only 3 feet 4 inches long, but still indicated an animal equal in size with the largest living Indian elephants. With respect to the species of elephant to which these remains belonged, Mr. Gunn exhibited molar teeth obtained from the same localities, showing that the

* Transactions of Bombay Geographical Society for 1845.

gigantic species was most probably the *Elephas meridionalis* of Nesti, whose remains are found in the pliocene formations of the south of Europe, and whose existence as a characteristic fossil of the British crag and its equivalent freshwater deposit at Grays, had been fully determined by Dr. Falconer, and confirmed by the observations of Mr. Waterhouse. The smaller species appeared to be identical with the mammoth or Arctic elephant of Siberia, whose tusks are remarkable for their double curvature, and the grinding teeth for the great number of enamel plates. The bones of this animal are less mineralized than those of the older species; they have been found over all Northern Europe, they are dredged in many parts of the British Channel, and occur in some of the caves. They are closely connected with the strata containing spruce fir-cones at Bacton, and with those newest beds containing Arctic sea-shells and other indications of a colder climate.

On the Distribution of Granite Rocks from Ben Cruachan. *By* William Hopkins, *M.A., F.R.S., Pres. Geol. S.*

Mr. W. Hopkins exhibited a map of the lochs and mountains around Ben Cruachan, with the distribution of the trains of granite blocks to which he had alluded last year at the Edinburgh meeting. He had formerly been unable to explain by what means the granite blocks supposed to have been derived from Ben Cruachan had crossed the mountain group between Loch Fyne and Loch Lomond, so as to gain access to the latter, and form a stream extending to the Clyde and Glasgow. Since then, he had discovered in this very mountain group a granitic tract not marked on the geological maps, in the immediate vicinity of Loch Sloy, at a height of from 1500 to 2000 feet, and agreeing in mineral character with these travelled blocks, which may therefore have descended Loch Long and Loch Lomond with the same facility that the granite blocks of Ben Cruachan have entered Loch Awe, and those of Loch Etive have reached Oban and Kerrara. They are dispersed along the sides of the valleys to the height of 300 or 400 feet. Mr. Hopkins then referred to the possible causes of the dispersion of the granite blocks;—if by ocean currents, then the country must have been depressed nearly 2000 feet, as Wales is believed to have been about the same period; if transported by floating ice, independently of glaciers, then also the country must have had a lower level; terrestrial glaciers may also have been agents, if their existence was allowed. The character of the blocks—being at first large and angular, but becoming smaller and more rounded,—was opposed to the supposition that floating ice or terrestrial glaciers were the principal agents in their removal. If floating ice had been the cause, then the sphere of dispersion would probably, also, have been much greater. In Glen Wray he had observed indications of what he considered true moraines. He was inclined to believe that more than one of these causes had been in operation in the dispersion of these blocks from their respective centres.

On the Age of the Copper-bearing Rocks of Lake Superior and Huron, and various facts relating to the Physical Structure of Canada. *By* W. E. Logan, *F.R.S. & G.S., Director of the Geological Survey of Canada.*

In the present paper it is my purpose to place before the Association, in as condensed a form as possible, one or two of the main features of the physical structure of Canada, ascertained in the progress of the geological survey now carried on in the country, under my direction, by the authority of the provincial government.

With the exception of the drift, the country is composed of rocks, none of which are newer than the carboniferous epoch. The general geographical distribution of these rocks, as far as ascertained and as connected with the physical structure of the bordering states of the American Union on the one hand, and the sister British provinces on the other, is represented on the map which is displayed to view.

One of the points to which it is my wish to draw attention is the age of the copper-bearing rocks of Lakes Superior and Huron, as determined by the evidences collected on the Canadian survey; and another, the differences that exist in the structural condition of the western and eastern parts of the province.

The rocks on the north shore of Lake Superior consist of reddish granite and syenite, which in ascending order pass into micaceous and hornblendic gneiss and allied

forms. These are succeeded by chloritic and partially talcose slates, which become interstratified with obscure conglomerates with a slaty base, and upon them rest unconformably bluish slates, with intermingled bands of chert and limestone towards the bottom, and a thick and extensive overflow of greenstone trap at the top. Reposing on these are white sandstones, which pass by an alternation of colours into red sandstones and conglomerates, often with jasper pebbles, and these are repeated after the occurrence of an uncertain amount of reddish limestone of an argillaceous quality. The sandstones and conglomerates become interstratified with amygdaloidal trap layers, and an enormous amount of volcanic overflow divided into beds crowns the summit. The sandstones are often argillaceous, and display ripple-mark and crack casts on their surfaces, while the concentric curves of flow sometimes characterize those of the trap. Innumerable dykes cut up the sedimentary and volcanic beds, and both the dykes and the overflows are almost universally marked by a transverse columnar structure. The thickness of the whole from the base of the blue slates cannot be less than 12,000 feet, and the whole formation is intersected by copper lodes of different characters in different places, which run in directions both with and transverse to the strike.

On the north shore of Lake Huron the granite is succeeded by a formation consisting of white, often vitreous sandstone or quartz rock of great thickness, sometimes passing into a beautiful jasper conglomerate, and alternating with great beds of slate and bands of conglomerate with a slaty base, both being interstratified with thick masses of greenstone. A persistent band of limestone of about 150 feet in thickness and interstratified with thin cherty layers, occupies a place in the series, probably somewhere about the middle. The surfaces of the sandstone often exhibit ripple-mark, and the total thickness of all the members of the formation may be about 10,000 feet. Different intrusive rocks intersect those of stratification, and as related to one another, they display a succession of events in the history of the formation. There is of course a set of dykes—greenstone no doubt—cutting the sedimentary rocks and giving origin to the greenstone overflows. It is difficult however to identify these; but another set of greenstone dykes are seen cutting both the sedimentary and igneous strata; intrusive granite, sometimes occupying considerable areas, thrusts these antecedents aside, sending forth dykes of its own order, intersecting all and reaching to considerable distances from the nuclei; and then another set of greenstone dykes cuts through the intrusive granite, its dykes, and all that previous causes had placed. Evidences of disturbances and dislocations accompany all these successive intrusions, those connected with the granite being the most violent. But there is in addition another set of disturbances of still posterior date, and it is to these that is due the presence of those metalliferous veins which give the country its value as a mineral region.

In respect to the age of the Huron cupriferous formation, the evidence afforded by the facts collected by my friend and associate, Mr. Murray (published in our Report of Progress for 1847–48), on the Grand Manitoulin, La Cloche, Snake, Thessalon, Sulphur, and other islands, points ranging along a line of 90 miles out in front of the coast, is clear, satisfactory and indisputably conclusive. On these islands, the Potsdam sandstone, the Trenton limestone, the Utica slates, and the Loraine shales, successive formations in the lowest fossiliferous group of North America, were each, in one place or another, found in exposures denuded of all vegetation, resting in unconformable repose, in a nearly horizontal position, upon the tilted beds and undulating surface of the quartz rock and its accompanying strata, filling up valleys, overtopping mountains, and concealing every vestige of dykes and copper veins; and it would appear that some of these mountains have required the accumulation of the whole thickness of the lowest three and part of the fourth fossiliferous deposit, equal to about 700 feet, to bury their summits.

The chief difference in the copper-bearing rocks of Lakes Huron and Superior seems to be the great amount of amygdaloidal trap present among the latter, and of white quartz rock or sandstone among the former. But on the Canadian side of Lake Superior there are considerable areas without amygdaloid, while white sandstones are present in others, as on the south side of Thunder Bay, though not in the same vast amount, or the same state of vitrification as those of Huron. But notwithstanding these differences, there are such strong points of resemblance in the

interstratification of igneous rocks, and the general mineralized condition of the whole, as to render their proximate equivalence highly probable; and the conclusive evidence given of the age of the Huron would thus appear to settle that of the Lake Superior rocks in the position given to them by Dr. Houghton, the late State Geologist of Michigan, as beneath the lowest known American fossiliferous deposits; and in this sequence those of Lake Huron, if not those of Superior, would appear to be contemporaneous with the Cambrian series of the British Isles.

The eastern limit of this formation on Lake Huron is in the vicinity of Colling's Inlet, opposite the eastern extremity of the great Manitoulin Island, whence it gradually recedes inland, taking a north-eastern-course; and farther down the St. Lawrence and its lakes, the Lower Silurian appear to rest upon gneissoid rocks without the intervention of the Cambrian.

If a line be drawn on the map in continuation of the Hudson River and Lake Champlain valleys to the vicinity of Portneuf, about thirty miles above Quebec, and thence in a north-eastward direction, it will divide the country into two areas, which, though nearly resembling one another in the general formations of which they are composed, yet present important differences in their structural condition. Each area belongs to a great trough of fossiliferous strata resting in Canada, with the exception of the supporting Cambrian formation of Lakes Huron and Superior, on gneissoid rocks, and containing coal measures in the centre, and the conditions, in which the two areas differ, are the general quiescence and conformable sequence of the formations from the base of the Lower Silurian upwards in the western, and the violent contortions and unconformable relations of those of the eastern. The coal measures of the eastern area are those of Rhode Island, and in a metamorphic state of Massachusetts, and those of Nova Scotia and New Brunswick. None of the productive part of the New Brunswick coal measures reaches Canada, but there comes out from beneath it, on the Canada side of the Bay Chaleur, 3000 feet of carboniferous red sandstones and conglomerates. These are succeeded by 7000 feet of Devonian sandstones, which rest upon 2000 feet of Upper Silurian rocks consisting of limestones and slates. The base of the Upper Silurian group has been traced a distance of about 700 miles from Gaspé on the Gulf of St. Lawrence, first to Memphramagog Lake in Canada, thence to Halifax on the southern limit of Vermont, and further into Massachusetts, keeping in its outcrop at a variable distance from the coal. In the interval, between the Upper Silurian and the carboniferous formations, there can be little doubt the Devonian sandstones will display a conspicuous figure in the eastern area, as they are known to be still 2500 feet thick in the eastern portion of the western area, in which they do not die away until reaching the banks of the Mississippi. In the eastern area the Lower Silurian strata sweep round the Upper, occupying a zone of between 40 and 50 miles broad; and the lowest rock common to both, connecting the troughs on the anticlinal, in the valley of Lake Champlain, is the Trenton limestone.

On the north-western side of the western area the formations are in a general flat and quiescent condition from Lake Superior to Pennsylvania, and they succeed one another, without any observed want of conformity, from the base of the Lower Silurian to the summit of the carboniferous. But it has been shown by Professors Rogers, that proceeding from north-west to south-east there occurs in this state a set of successive parallel undulations which increase in intensity in the direction mentioned, and on the south-east side of the Apalachian coal-field are sufficiently violent to produce overturn dips in all the formations together, the coal inclusive. These plications with their overturn dips thus form the south-eastern rim of the western area, and are distinctly traceable by the Apalachian chain through Vermont into Canada, and through Canada to the Gulf of St. Lawrence; in this part constituting the north-western rim of the eastern area. But while in the western division there is no want of conformity from the Lower Silurian rocks to the carboniferous, and the plications there appear to be of a date subsequent to the carboniferous deposit, in the eastern there are evidences of a want of conformity between the Upper and Lower Silurian formations, and though the folds in the former do not seem quite so violent, they are in parallel directions with those in the latter. There is another and a greater want of conformity between the Devonian rocks and the carboniferous. A large portion of the carboniferous deposit of New Brunswick shows but very moderate

dips, and on the shores of Bay Chaleur it lies in a quiescent condition on the tilted edges of the lower formations, sometimes resting on one and sometimes on another. Its north-western outcrop however, or rather, I should say, the longitudinal axis of the whole coal-field from New Brunswick to Newfoundland, has a parallelism with the folds of the inferior rocks, and there are several parallel undulations in nearly the same direction on the south side of the carboniferous deposit.

The conclusion to be drawn from these facts appears to be, that some cause producing folds in the stratification in one general direction has been in operation from at least the cessation of the Lower Silurian epoch to the termination of the carboniferous; and it only requires the inspection of a map of Atlantic America to observe how the features of its physical geography, displayed in the configuration of its coast, in its valleys of undulation and those of transverse fracture, are almost entirely dependent on the results of this cause.

The fossiliferous rocks of both these divisions, with the exception of that part supported by the Cambrian formations of Lakes Superior and Huron, rest, along the valleys of the St. Lawrence and the Ottawa, upon a series consisting of micaceous and hornblendic gneiss interstratified towards the south with great bands of crystalline limestone, sometimes highly charged with magnesia and associated with vast masses of magnetic iron ore, but without calcareous beds on the north. These rocks constitute a part of the low granitic ridge, which to the westward has been traced by Sir J. Richardson as extending with a north-westerly curve to the Arctic Ocean.

The Canadian rocks on the north side of this granitic ridge, as displayed toward the head of Lake Temiscamang, consist, in ascending order, of chloritic slates and conglomerates with a slaty matrix; the volume of these is probably not less and may be much more than 1000 feet. On them rests a set of massive pale greenish-white or sea-green sandstones, the total amount of which, as determined by the height of hills which they compose in nearly horizontal layers, is between 400 and 500 feet. These are succeeded by about 300 feet of buff and whitish fossiliferous limestones, the lowest bed of which is composed of a collection of great boulders and blocks of sandstone, some of them 9 feet in diameter, that were lying immediately on the strata from which they were derived when they became covered up, and in which great cracks and worn fissures are filled with the calcareous deposit that envelopes the whole. The sandstones being without discovered fossils, it is not easy to determine their age; but the limestones by their organic contents are distinctly shown to belong to the Upper Silurian epoch. The Lower Silurian deposits, unless the unfossiliferous sandstones be a member of the group, appear to be wholly wanting in the locality, and as all the forms brought from other localities on the north side of the granitic ridge by Bigsby, Richardson and others, are, I believe, referable to Upper Silurian types, it appears not improbable that the absence of the Lower Silurian rocks may spread over an extensive area, and the south side of the ridge indicate an ancient limit to a Lower Silurian sea.

The nearest locality of the well-defined forms which inhabited this sea is at the island of Allumette, about 200 miles southward from the Upper Silurian rocks of Lake Temiscamang; there is however a patch of the same lower formation which is only about 100 miles southward from them, but in it the fossils are obscure. Instead of giving any remarks of my own on the fossils of the two sides of the granitic ridge, I shall append to my paper a note which my friend Mr. Salter of the Geological Survey of the United Kingdom has been so kind as to make on them after a careful inspection, only stating that the specimens which have been examined are but a small part of an important collection, chiefly from the eastern of the two divisions that have been alluded to, brought from Canada for comparison, and that twice as many specimens as have been brought remain in the province from other parts, while great additions it is hoped will annually be made to them.

I have only further to add, that I exhibit to the Section as one of the characteristics of the lowest member of the Lower Silurian rocks of Canada, a small slab of sandstone and a cast from a larger one, showing what Professor Owen has, in a communication to the Geological Society, pronounced to be a track and footsteps of a species of tortoise, thus proving the existence of reptiles at the very earliest period of known animal life; a fact, upon the importance of which it is unnecessary to insist before a geological audience.

Note on the Fossils above mentioned, from the Ottawa River. By J. W. Salter, *F.G.S., A.L.S.*

Lower Silurian.—The fossils from the S.E. end of Allumette Island, on the Ottawa River, are the only Lower Silurian fossils yet examined of Mr. Logan's large collections, and they bear out well the opinion he has expressed, that in some parts of Canada but one calcareous group can be distinguished between the Potsdam sandstone and the Hudson River group, agreeing in the main with the celebrated "Trenton limestone" of New York, but possessing also many of the fossils characteristic of the lower limestones which in that country have received separate names.

For instance, one of the most abundant fossils is a species of *Scalites* (*Euomphalus uniangulatus*), described as a fossil of the calciferous sand-rock by Hall. The corals, again, *Stromatocerium rugosum, Columnaria alveolata,* which are very abundant, are those of the Bird's-eye and Black River limestones. The former of these corals, too, is usually found investing (after the manner of a sponge) a large and fine species of *Maclurea,* a genus of gasteropods which in New York does not mount above the "Chazy" or lowest limestone, and is there abundant. Hall indeed expressly mentions that the *Stromatocerium* occurs in beds above those which contain the *Maclurea.* In this case, however, the parasitic zoophyte has generally selected this fine and new shell, to which I propose giving the name of its discoverer. It is well distinguished from *M. magna,* by the much more rapid increase in diameter of its whorls, and its minute umbilicus. It is possessed moreover of a most peculiar operculum, which will at once establish the right of *Maclurea* to rank as a distinct genus, being furnished within with a broad and strong bony process for the muscular attachment, and being itself very strong and massive. Prof. Forbes has undertaken to compare this peculiar operculum with that of some rare living gasteropods of far inferior size, so that more need not be said of it at present.

The *Stromatocerium* affects also a small and new species of *Scalites* allied to the one above-mentioned, and frequently covers all but the mouth, so as to mask the form of the shell completely.

But it is with the Trenton limestone that the greater number of species agrees; and while a large portion of them, especially the gasteropods, appear to be undescribed in Hall's work, still the analogies are very evident. A list of ten or more *Murchisoniæ* or *Pleurotomariæ* affords one, *M. ventricosa,* characteristic of the Bird's-eye limestone; two common in the Trenton limestone, *M. bicincta* and *M. gracilis* (very abundant species), and *M. bellicincta,* Hall, a large *Turritella*-like form; the rest seem to be new; and some of them are remarkable for the tendency of the whorls to separate and become what may be called vagrant, as happens in some accidental varieties of the common snail. The shells are tolerably thick and strong.

Some smooth shells, exactly like the *Euomphali* of the carboniferous limestone, and several roughly sculptured *Turbines* or shells of apparently allied genera, occur; and one exceedingly elegant, with close thread-like lines of growth, is very common. *Holopea* of Hall, an ill-defined genus, offers one or two species of the typical form, and one closely allied to *H. bilix* of the Western States. There are three species of *Scalites,* a genus with the mouth notched like *Pleurotomaria,* but destitute of a spiral band: one is the small species so commonly encrusted over; a second, of which we have but a single specimen, is muricated with spines, like a *Delphinula*; the third is the very common *S.* (*Euomphalus*) *uniangulatus* above mentioned, which also, but rarely, shows a tendency to become spinose. There are also two or three species of the genus *Raphistoma,* which appears to be only a discoid form of *Scalites.* We have a *Turritella*? spirally ribbed, and undistinguishable in general form from living species. But the most abundant and characteristic shell is the *Maclurea,* fragments of which, with scattered opercula, occur on almost every surface.

Among bivalve shells, which chiefly belong to the *Arcacidæ,* a very interesting new genus has rewarded examination. It was found that two species resembling *Nucula* in every general character, differed from it importantly by having no internal ligament, but a very manifest exterior one*; one of these shells measures three inches across, and from the general analogy of several accompanying species it is

* Mr. S. P. Woodward, of the British Museum, suggests that *Solenella* may contain these species.

believed that the genus will be found common in the Silurian rocks, and will include many species now referred to *Nucula*. It might be called *Ctenodonta*. Of the same family also, a *Lyrodesma* (a genus with radiating teeth beneath the beak and synonymous with *Actinodonta*, Phillips) is closely allied to a Trenton limestone species. There is a new genus probably belonging to the family Arcacidæ, but possessing only two or three anterior teeth; the collection does not include any *Aviculæ*. Of the few lamellibranchiate shells none appear quite identical with those from New York; but, as might be expected, the common *Brachiopoda* of this locality are those most abundant also in the Trenton limestone. *Orthis tricenaria*, Conrad, swarms here, as does also *Leptæna filitexta*, Hall, a shell very like the common *L. alternata* of the Trenton limestone, but reversed as to the convexity of the respective valves. But the latter shell, so abundant in New York, does not occur here. *Atrypa hemiplicata*, Hall, and *A. increbrescens* are tolerably frequent; and there are two or three species of *Orthis*, and some small *Terebratulæ*, which require further examination.

The *Bellerophons*, two of which are probably identical with New York species, are those of the lowest or chazy limestone, namely, *B.* (*Bucania*) *sulcatina*, Emmons, and *B. rotundata*, Hall. The group to which these two belong is that of which the English *B. dilatatus* is a familiar type, the whorls scarcely enveloping each other, and the mouth wide and trumpet-shaped. There is however a true *Bellerophon* so like *B. obtectus*, Phill., from the Ludlow rocks of Pembrokeshire, that, but for its treble size, it might be taken for it.

Perhaps one of the most interesting of the mollusks is a large *Cleodora*, quite new to America, and not yet described as such from Britain. On attentively comparing the American, Irish and North Welsh specimens of this fine shell, which measures two inches across, I can find only trivial variations. It does not require a new specific name, having been figured from an imperfect specimen as *Atrypa transversa* by Portlock. It is interesting to find this species (which of course, as a Pteropod, had ready means of migration) in the two countries. There are but few other species identical with those of Great Britain, but I think I recognise *Turbo trochleatus*, and perhaps *T. tritorquatus*, M'Coy, as common to the two regions.

Of the Cephalopoda, the remarkable two-edged *Orthoceras*, called *Gonioceras anceps* by Hall, is a Black River limestone species. *Cyrtoceras* is common, both smooth and ornamented; *C. annulatum* and *C. lamellosum*, the same with those of Trenton; *Orthoceras arcuo-liratum*, *bilineatum*, and *laqueatum*, Hall, are Trenton limestone species; and lastly, there are two species of *Ormoceras*, Stokes, the larger of which is in all probability *O. tenuifilum*, Hall, a species both of the Black River and Trenton beds.

Schizocrinus nodosus, Hall, of the Trenton limestone, is the common crinoid: its stems are very characteristic.

Among the corals, one or two species of *Streptolasma*, apparently the same as those of New York, and the branched varieties of *Favosites lycoperdon*, accompany those before mentioned; and we may here notice the *Receptaculites*, already described by Hall, but not I think identical with *R. Neptuni* of Europe. The fine series brought home by Mr. Logan shows all the structural characters;—the circular expanded form and cup-like centre,—the surface composed of rhomboidal plates, which cohere by lateral processes, and which are the flattened ends of separate and equidistant columns. Unfortunately the entire structure is replaced by cycloidal silex, but perhaps it will by careful polishing enable us to see if it be really a coral, somewhat of the character of the *Tubiporidæ*.

To crown all, these are slabs full of the large *Asaphus* (*Isotelus*) *gigas*, the characteristic trilobite of the Trenton rocks.

Upper Silurian Rocks.—Ascending the Ottawa to the head of Lake Temiscamang and so crossing the granitic axis of Canada, the first fossiliferous rock that presents itself is of a totally different character to that last described, as stated by Mr. Logan in his Report of Progress for 1845.

This limestone is weathered like the last; its siliceous fossils also stand out in bold relief; and one of the most common is the characteristic crinoid of the Trenton limestone, *Schizocrinus nodosus*, at least I believe I am correct in this reference. But along with this are abundance of *Favosites gothlandica*, *Stromatopora striatella*, *Cyatho-*

phyllum, a *Heliolites* (*Porites*), with small tubes; *Syringopora* (*Harmodites*) with *Halysites catenulatus* (*Catenipora escharoides*), and *Strombodes striatus*, Milne Edwards, fossils characteristic of the *Niagara* and *Onondaga* limestones, and in America never found in the lower rocks; with these occur *Atrypa reticularis* in plenty, a *Terebratula* with three raised plaits, and very rarely a *Leptæna* or *Strophomena*. One or two spiral shells recall the shapes of some of Hall's species of *Holopea*, but are too imperfect for identification; and there is a long spiral shell, like *Murchisonia gracilis*. *Encrinurus punctatus* is the only trilobite.

The most striking shell perhaps is a species of *Ormoceras*, the short broad siphuncles of which are well preserved, while the shell has decayed; and these so much resemble those figured by Dr. Bigsby and Mr. Stokes in the Geological Transactions, 2nd series, vol. i. pl. 30, figs. 4, 5, 6, 7, that we think there can be no doubt of their identity. And it is very interesting, as bearing on the question of age, that these were found at Drummond Island, the only limestones of which are Upper Silurian.

Indeed the whole aspect of this collection, small as it is, is as strikingly Upper Silurian as that of the former one was Lower Silurian. The preponderance of the *Catenipora*, *Favosites* and *Stromatopora*, &c., is characteristic of the higher rocks, and they are associated with *Pentamerus oblongus* (the characteristic fossil of the Clinton group, which may be regarded as the base of the upper division), and this shell in America is far more limited in its vertical range than it is in Britain.

Professor E. Forbes exhibited the new species of *Maclurea* referred to by Mr. Salter, and its operculum, and stated that he regarded it as one of the floating forms which appear to have been common in the Silurian period.

On the Occurrence of a Stratum of Stones covered with Barnacles in the Red Crag at Wherstead, near Ipswich. By Sir Charles Lyell, *F.R.S.*

It has been observed that in the Red Crag of the neighbourhood of Ipswich, and generally throughout the area occupied by that formation in Norfolk and Suffolk, the marine organic remains are not now in the places where the animals to which they belonged lived and died. They are mixed with pebbles, and often, like them, bear the marks of having been rolled. The valves of the bivalve mollusca are found detached one from the other, and neither they nor the univalve shells are arranged in groups as they lived at the bottom of the sea. They look as if they had formed portions of shifting sand-banks, or as if they had been drifted from some other place to that where they are now met with. Every exception, therefore, to so general a rule deserves notice, and I shall mention one now to be seen in the Crag within a few miles of Ipswich, about 500 yards south of the vicarage-house of Wherstead, to which attention was called by the Rev. Barham Zincke of Wherstead. The shelly red crag here laid open has a vertical thickness of from 10 to 12 feet, and is overlaid by 8 feet of sandy and gravelly beds without fossils. The shelly mass presents the usual characters of this formation, and among others, that of having the separate valves of the *Pectunculus*, *Mactra*, *Cardita*, *Pecten* and *Terebratula* with their concave sides turned downwards, almost without one exception. Near the top of the shelly mass, usually within 18 or sometimes 8 inches of it, a stratum occurs consisting of unrounded chalk flints intermixed with some well-rounded flint pebbles. The upper portions of these stones, which are of various sizes, are encrusted with barnacles from which their lower surfaces are free. The barnacles consist chiefly of a littoral species, *Balanus communis*, and another nearly allied to it. The longest of the stones obtained by Mr. Zincke from this bed, and which he has brought to the meeting, is an unrounded chalk flint, measuring no less than 22 inches in length, by 16 in breadth, and 7 in height. It supports on its top and sides about ten groups of barnacles, but none of these are found on the under side of the stone, where it must have rested on the bottom of the sea. The same remark holds good in regard to all the other stones and pebbles spread through the same stratum. Among these Mr. Zincke and I observed a small coprolite, or one of the bodies commonly so called, the top of which was covered with barnacles, while all the lower portion was smooth. The pebbly stratum containing these *Balani* is overlaid with shelly crag, of somewhat fine materials, and of slight thickness, as

before stated. From the above facts it appears, that the action of those currents which brought the principal mass of crag to this spot, and which had power to convey to it some stones of no ordinary magnitude, was so completely suspended for a time, that even the smallest and lightest pebbles were not moved or overturned. Had any of them been turned over we should have found barnacles on the lower sides of them, or perhaps on both sides; nor did any current wash away the loose shelly layer that afterwards covered the barnacle bed. The *Balanus communis* is a littoral species, and Mr. Searles Wood informs me that he has generally met with it in the upper part of the Red Crag. Professor E. Forbes, to whom I have shown the specimens, says that the time required for such a growth of barnacles may have been three or four months, and that they probably lived in very shallow water, if not between high- and low-water marks.

On the Scratched and Polished Rocks of Scotland.
By Sir Roderick I. Murchison, *G.C.St.S.*, *F.R.S.*, *Pres. Geogr. Soc.*

The author first gave a brief sketch of the whole subject of abraded, polished and striated rocks, to which for many years he had paid attention, by comparing the phænomena in the British Isles with those seen in Scandinavia, Russia, the Alps, and other parts of the continent. He showed how effects which had been exclusively referred by Agassiz and others to the action of ice moving on land, or glaciers, could now, in the vast majority of examples, be better accounted for by the agency of the melting of snow and ice, the driving forward of ice-floes by powerful currents, and the accompanying translation of vast quantities of drift composed of gravel, mud, sand, and erratic blocks.

Sir Roderick next described certain polished and striated rocks on the north shore of Loch Fyne, which he had examined last summer in company with the Duke of Argyll, particularly at the promontories of Kenmore and Penimore, where bosses of tough, crystalline chlorite schist are powerfully abraded and rounded off wherever they face to the E.N.E. or up the loch, and whose surfaces are rugged and natural on the W.S.W. or towards the sea. The portions of these rocks which have been so mechanically ground down, exhibit also rudely parallel and slightly diverging lines of striation, showing that they have been scored and fluted as if by the passage over them of a heavy harrowing mass which had been translated from E.N.E. to W.S.W., and the chief force of which had been expended on the faces of the rocks which stood out as opposed to it. The author then referred to several other examples of similar appearances in other parts of the seaboard of the West Highlands, particularly on the sides of the lochs which open out from Ben Cruachan and Loch Etive to Oban, the rounded and striated surfaces of the promontories and islets being invariably presented towards the interior, and their jagged and rough faces towards the sea. He also referred to his writings on the countless examples of *precisely similar* phænomena in Sweden, in which flat country he had endeavoured to demonstrate, that they never could have resulted from the action of *terrestrial glaciers*, and he now applied the same reasoning to the lower parts of Scotland.

Alluding to the lines of striation cited by Mr. Robert Chambers and other authors as occurring in the eastern counties north of Edinburgh, where the direction has been from west to east, or nearly opposite to that mentioned on the west coast, Sir Roderick then called special attention to a fact which in September 1850 came under the notice of Professor Nicol and himself near Glenluce in Galloway. There the sea-shore trends from west to east, and the drift-marks are, as in the other cases, more or less at right angles to it, being directed from north to south. In all these cases of striation, gravel, stones, and shingle had been recently removed from the surface of the rocks. From these data, which go to indicate that the drifted materials had in all cases been derived from the chief adjacent masses of land, the author expressed the opinion, that during the 'glacial epoch' Scotland probably consisted of a range of rocky hills in an icy sea, which by successive movements from different centres had thrown off dislocated sheets of ice, with much melted snow and ice, forming a detrital 'sludge' or drift which had been poured down all the lateral openings. In Scotland, therefore, as in Scandinavia, he accounted for the grinding down and striation of the rocks in the lower gorges and on the lower grounds near the sea, by the passage of such materials. At the same time he believes in the former existence in Scotland of

short terrestrial glaciers, and he compares the ancient condition of the upper end of Loch Fyne and other salt-water lakes of the West Highlands to the present fiords of Norway, where snowy ridges terminate seawards in glaciers which advance to near the water's edge. A sudden upheaval of such tracts would, in dislocating the glaciers and in throwing off a mixed icy drift, he contends, produce appearances like those on the coasts of Scotland.

On new Fossil Mammalia from the Eocene Freshwater Formation at Hordwell, Hants. By Professor Owen, *F.R.S.*

The specimens described were from the collection of the Marchioness of Hastings, and belonged to the genera *Paloplotherium*, *Xiphodon*, *Dichodon*, and *Hyænodon*. The genus *Paloplotherium* (Owen) is the link which connects the Tapir, Rhinoceros and Palæothere with the Hippothere and Horse. It differs essentially from the Anoplotherium in having a long interval between the molar and canine teeth, and in having the external nostril formed by six bones instead of four. From Palæotherium it differs in having only six molars on each side of the upper jaw. The species (*P. annectens*) found at Hordwell also occurs in the lignite formation of Gargas, Vaucluse. The genus *Dichodon* agrees with *Anoplotherium* in having an uninterrupted series of teeth; remains of two species (*D. cuspidatus* and *dorcas*) have been found at Hordwell. Of the genus *Xiphodon* an almost entire lower jaw (distinct from the *X. gracilis* of Cuvier) has been obtained; also an entire lower jaw of the *Hyænodon*,—a genus "so remarkable amongst the carnivorous order for retaining the normal formula of the dentition of monophyodont placentals, and for the truly carnassial form of the three true molars." The Hordwell specimen agrees with the *H. minor* of M. Gervais, from the lacustrine marls of Alais.

On the Fossil Mammalia of the Red Crag. By Professor Owen, *F.R.S.*

On the Structure of the Crag. By John Phillips, *F.R.S.*

The author presented in the first place a general view of the geological constitution of the country round Ipswich, illustrating the vertical succession, horizontal area, mineral character and organic contents of the visible strata, the lowest of which is chalk. Referring then to the admirable labours of Mr. Searles Wood, by whom the numerous testacea of the Crag had been beautifully described and figured; to Professor Owen, to whom the distinction of many unexpected mammalian forms in this deposit was due; and to Mr. Colchester, who discovered the oldest of these forms; to Mr. Charlesworth, who first classed the Crag into the three departments of Coralline, Red and Mammaliferous Crag; to Lyell, Forbes and Prestwich, and finally to Henslow, who called attention to the now very profitable mass of phosphatic nodules ('coprolites'), the author limited his following remarks to certain facts in the physical structure of the Red Crag, which appeared to throw a definite light on the condition of the waters and sea bed, at the epoch when this rich shelly deposit took place.

First, he showed that the London clay, the general base of the whole deposit of the red and coralline crags, had been enormously wasted by the sea, and reduced to a thin portion with a nearly level though uneven top. On this the red crag was deposited, in laminæ very frequently deviating from the horizontal, often inclined in different directions, more or less filled with a rude mixture of shells, entire or broken or worn, most frequently with valves separated; pebbles of flint and water-worn lumps of bone, phosphatic nodules, sharks' teeth, and a variety of other substances. Towards the base of the deposit, in many irregular streams or veins, the larger and heavier of these nodules were often collected together, and sometimes mixed with great lumps of chalk flint. Above and below these veins of (so-called) coprolite, was usually a series of nearly horizontal bands of argillaceous marl, throwing out water; sometimes two of these layers of nodules occur, the lower being then thickest. In other places, where coprolites do not occur in abundance, the lower parts of the red crag are formed by alternating thin clays or loams (probably derived from the London clay beneath), and thin bands of coarse shelly crag. Thus, intervals of comparative tranquillity are seen to have intervened between recurring periods of watery agitation. In the highest parts of the deposit a vast variety of the effects of agitated water occur, and proof at

every step of deposition disturbed by drifting. Selecting from a variety of subjects two cases of interest, the author described, above the middle of the red crag, a band some feet in thickness which was traceable for half a mile on the Felixstow cliff, and had in all that range apparently one direction of the inclination of its laminæ, viz. to the S.W. or nearly so, and in several parts of this range showed these laminæ to be *curved*, with the concavity upwards, the inclination of each lamina being greatest near the surface (30°), and thence declining away, so as, in the space of 30 or 40 yards, to become horizontal.

This result the author showed to be analogous to what happens in certain beaches of modern date, and is in fact exemplified on the very beach which extends below the crag, and is now spreading out continually further to sea. Another interesting character of the mechanical conditions under which red crag was deposited, is found in the position occupied by the separated pieces of bivalve shells. These (as first pointed out by Mr. R. Johnson in the Proceedings of the Geological Society) were, when in a state of tolerable completeness, very commonly found with their concave sides downwards, a position which the observer alluded to conceived to be inconsistent with this arrangement of water, and ascribed to currents of wind. Professor Phillips showed, on the contrary, by mechanical considerations, and by references to actual experiments, that this was the very position which such shells must and do take up in finally settling to rest from frequent agitation in water, such as happens on a sea beach; and that no other explanations ought to be admitted. Abundant proof of this was afforded by trials with the crag shells and recent shells on the beach at Felixstow. In some places, alternating with these inclined laminæ, and defining them, were laminæ of loam or micaceous sands not shelly—evidently due to subsidence from muddy waters settling to comparative quiet. Thus again intervals of agitation and comparative repose were proved to have alternated, and this in a way to correspond with what is observed on modern beaches.

In regard to the conditions of land and sea during the accumulations of red crag, the author stated in general terms his opinion that those deposits took place in a sort of shallow bay, receiving matters from wasting cliffs and shifting shelly sands, by a current varying in intensity, and subject to one or more specially tumultuous epochs.

Lieut.-Colonel Portlock exhibited Fossils collected by Mr. R. Rubidge at Sunday River, on the Cape frontier. They consisted of marine shells of the genera *Ammonites*, *Gryphæa*, *Pholadomya* and *Trigonia*; and plants of the genera *Zamia*, *Neuropteris*, *Pecopteris* and *Sphenopteris*. The shells were apparently of Jurassic age; the plants had been examined by Dr. Harvey, and the species of *Neuropteris*, *Pecopterls* and *Sphenopteris*, were regarded as chiefly resembling those of the coal of Australia, whilst the presence of the genus *Zamia* in abundance impresses an oolitic aspect on the flora.

Explication d'un Tableau de l'Etude Méthodique de la Terre et du Sol. *By* M. Constant Prévost.

Mr. Prestwich, at the request of the President, explained that M. Prévost's object was to introduce uniformity into geological nomenclature, and also to give a more distinct meaning to scientific terms. At present each country had its own nomenclature, and many of the terms in use were invented at a time when the science was one of imagination. M. Prévost had always advocated the view that causes now in action were sufficient to account for all the phænomena of the older rocks; at the same time he started with the supposition that the earth was originally in an extremely heated condition. Round this heated globe a thin crust (*sol*) was formed, and gradually thickened by sedimentary deposits going on in all times, whilst volcanic outbreaks were continually occurring from the interior. M. Prévost divided all the strata into systems or series (*terrains*), representing periods of time, each necessarily including marine, fluvio-marine, freshwater, terrestrial and volcanic deposits (*formations*). But although the causes of each of these kinds of deposit must have been in operation during every past epoch, it may be doubted whether we shall ever discover the equivalents—freshwater, terrestrial, volcanic, &c.—of every one of the known marine formations.

The Rev. T. Rankin stated that the parish church of North Dalton, near Beverley, stands on a small mound with a pond below. The mound is a mass of chalky gravel, usually supposed to be artificial, but the writer regards it as a mass of drift left by currents, and assigned his reasons for the opinion.

Mr. C. B. Rose exhibited the Antler of a Rein-deer, found by Captain Alexander below the cliff near Southwold, and probably derived from the glacial deposits of which the upper part of those cliffs is formed. As it was the first occurrence of the animal in Suffolk, he presented the specimen to the Ipswich Museum. He also showed a very small recent-looking antler of a fallow-deer obtained from a fen at Roydon, near Diss. It was found at the depth of 4 or 5 feet, associated with remains of the Red-deer, Roebuck and Ox. Mr. Rose quoted the opinion of Dr. Fleming, that the fallow-deer was a native of Britain*; Dr. F. having referred, among others, to Lesley (De Or. Scot. p. 5), who mentions, among the objects which the huntsman pursued with dogs, "Cervum, *damam*, aut capream;" in which he was supported by Mr. Strickland, who remarked also, that the Rein-deer had been found with the Irish Elk in the marl under a peat bog on the coast of Holderness.

On Klinology in reference to the Bavarian Alps. *By* Dr. Schafhaeutl, *of Munich.*

The Alps surpass all other European mountains both in grandeur and in complexity of geological structure. Their central ranges consist chiefly of crystalline and metamorphic rocks,—their borders of sedimentary strata; some of the newest of these strata have the greatest breadth, elevation, and mass, attaining a height of 10,000 feet above the sea. Fossils are often very scarce; and when they do occur, those of several formations have become mixed together, on account of the frequent repetition of the formations by mechanical displacement. Dr. Schafhaeutl recommends the study of the intimate structure of the beds,—a mode of investigation which he terms "Klinology." It has long been admitted that the newer rocks have generally a lower specific gravity, and are less compact or crystalline than the older strata; and the remarks of Ehrenberg have shown that the microscope may be employed to detect minute structural as well as organic peculiarities. Even by placing rock specimens in distilled water, outlines and designs may be brought out which were before invisible; and still more may be learned by the application of hydrochloric acid, or by studying weathered surfaces. As examples of the importance of attending to minute characters, the author mentioned that the red sandstone of Berchtesgäden had been considered the equivalent of the old red schists of Salzburg; but he had detected the existence of green particles in this sandstone; and had traced them to a distance increasing in numbers until the red sandstone became green, and was clearly recognizable as a lower member of the Cretaceous group. In a similar manner he had ascertained that the black lias-like schist of M. Beseler, in the western Bavarian Alps, was also "greensand." Microscopic fragments of characteristic shells, like the *Caprotina*, had been found by him where entire specimens were wanting; and in some of the lofty Alpine limestones which are destitute of fossils, he had detected microscopic remains which showed their origin, like that of the chalk formation, to have been intimately connected with "the wide-spread and powerful-working spirit of life developing itself in forms invisible to the unassisted eye."

On the Geology of a part of the Himalaya and Thibet. *By* Captain Strachey, *Bengal Engineers.*

Captain Strachey pointed out on a large map the great elevated region of Central Asia, extending from the sources of the Oxus to the Yellow River of China; bounded on the north by the Kouenlun mountains, on the south by the Himalaya, which form the southern face of the elevated region, rather than a separately existing chain. Little is known of the interior and northern part of the region, but it appears to be broken up into a mass of mountains, where valleys as well as the ridges have a very

* The fallow-deer is usually considered to have been introduced from the East; it is represented on one of the Nineveh marbles. No unequivocal remains have been found fossil in Britain.

great elevation. The observations of the author relate to the centre of the Himalayan chain, between the river Kalee and the Sutlej, a space of 200 miles, and extending N.W. from the plain to a distance of 120 miles.

On some Tubular Cavities in the Coralline Crag at Sudbourne and Gedgrave in Suffolk. By SEARLES V. WOOD, *F.G.S.*

BOTANY AND ZOOLOGY, INCLUDING PHYSIOLOGY.

BOTANY.

On the Morphology of the Fruit in the Cruciferæ, as illustrated by a Monstrosity in the Wallflower. By Professor G. J. ALLMAN, *M.D., M.R.I.A.*

PROFESSOR ALLMAN laid before the Section a singular monstrosity which recently occurred to him in a plant of common wallflower growing in the Botanic Gardens of Trinity College, Dublin, and which appeared to throw considerable light on the morphology of the fruit in the Cruciferæ. The monstrosity consisted in the conversion of the six stamina into carpels, which faced the axis of the flower and carried ovules on both margins: in the greater number of instances these carpels were imperfectly closed, and were united by their margins into a tube which formed a complete sheath surrounding the pistil. In other cases however the adventitious carpels remained distinct, and each was then seen to be composed of an ovary, style and stigma. It was also evident that the ovary with the short style resulted from the transformation of the filament, while the stigma was plainly a transformed anther; but what was especially interesting was the distinctly bilobed condition of the stigma in these solitary carpels; each lobe was evidently derived from a corresponding lobe of the transformed anther, and was placed opposite to the marginal row of ovules; the stigma indeed here closely resembled that of the normal fruit, and offered a very obvious explanation of the anomalous fact, that the stigmata in the latter appear to be situated opposite to the placenta. We have only to suppose two of these adventitious and imperfectly-closed carpels to unite face to face, and a stigma with the exact formation which we find in the normal fruit of the Cruciferæ will be the result. The latter therefore is evidently formed of two bilobed stigmata, united so completely as to obliterate the traces of union, while the bilobed condition of the individual stigmata is in no respect interfered with; so that what appears as a simple element in the compound stigma of the cruciferous pistil is really composed of two half-elements, namely, one lobe of each of the two elementary stigmata. This opinion has already had its advocates, but it seems to have been hitherto urged on purely theoretical grounds. From all this it would seem further to follow that the ovary of the cruciferous carpel corresponds to a petiole or phyllodium, while the bilobed stigma will represent the lamina of the carpellary leaf.

In many of the adventitious and imperfectly-closed carpels a membranous expansion extends inwards from each margin over the concavity of the carpel, but without uniting with that from the opposite margin. These expansions correspond to the spurious dissepiment of the normal fruit, and are here plainly seen to be derived from the placentæ.

On some Facts tending to show the probability of the Conversion of Asci into Spores in certain Fungi. By the Rev. M. J. BERKELEY and C. E. BROOME.

After alluding to the observations of other botanists on this subject, the authors communicated as follows. The species which have afforded the materials for the following remarks are more especially three, viz. *Tympanis saligna*, Tode; *Sphæria inquinans*, Tode; and *Hendersonia mutabilis*, Berkeley and Broome. *Tympanis saligna* scarcely differs from a lichen, except in the total absence of a crust, and consequently of gonidia. Its apothecia are at first closed, but at a later period of growth the fructifying disc or hymenium is exposed. On the same twig, in this instance of the common Privet, some specimens exhibited all the characters of *Tym-*

panis, and others those of *Diplodia*. As long as the naked spores occurred only in specimens in which the disc was not expanded, this caused no surprise, as nothing is more common than to find Sphæriæ and Diplodiæ on the same matrix, which cannot be distinguished externally; but further examination exhibited the proper fructification of *Diplodia* in specimens with an open disc, a character quite at variance with that of the genus, and then the same hymenium was detected producing rather large uniseptate naked spores, and broad elongated asci exceeding them many times in length, and containing a multitude of minute oblong sporidia. Prof. Fries, in a letter lately received, informs us that he has observed a similar fact in "*Hendersonia Syringæ*." The circumstance of the constant or occasional occurrence of *Uredo* and *Puccinia*, *Uredo* and *Aregma*, *Uredo* and *Xenodochus*, or two species of the same genus in the same spot, may be adduced as analogous; but where there is no perithecium, the occurrence of two species on the same spot, of the same matrix, is not matter of so much surprise, though suggestive of further consideration. The case, however, of *Sphæria inquinans*, which we have now to bring forward, is still stronger. This species and *Stilbospora macrosperma* were extremely abundant on an old elm at Batheaston in January last. Not only were they so intermixed as to make it difficult—from the close resemblance of the fruit, that of the one being merely a little more elongated, and in a very slight degree more attenuated at either extremity, with rather a browner tinge—to say at once which was the *Sphæria*, which the *Stilbospora*, but the same orifice in the bark gave egress both to the sporidia of the one and the spores of the other. At the base of the spores of the *Stilbospora*, where they are seated on their sporophores, from one to three short sheaths were observed, as if the spore had burst through one or more enveloping membranes; but not only was the *Stilbospora* produced in the same portion of the bark as the *Sphæria*, or, perhaps, to speak more correctly, in the same stroma, but in one case it was actually developed on the external surface of a perithecium, the inner surface giving rise to perfect asci with their proper sporidia. In a certain stage of growth the sporidia of the Sphæria are furnished at either extremity with a cirrhiform appendage, but this is not always visible in the ejected mass which surrounds the common orifice of the perithecia. Analogous appendages occur in some other species. The third case to which we invite attention is *Hendersonia mutabilis*, a species which occurs on twigs of Plane. The main perithecium contains one or more cavities more or less isolated, which produce far smaller hyaline bodies, and which do not accord with the genus *Hendersonia*, but rather with *Phoma*. This is not indeed a case bearing upon the conversion of asci into spores, but is interesting as exhibiting one perithecium within another; and whether considered as a new cell developed within the old one, and consequently containing younger spores, a view at first adopted, but which, on mature consideration, seems scarcely tenable, or as two forms of spores both belonging to the same species, but produced in distinct cavities, or, finally, as two genera united within the same common receptacle, is full of interest. We are not prepared, as in the last case, to say that the same wall from its two sides produces different forms of fruit, though in some sections the two fertile surfaces are so confluent above, that it is very probable that the same fact will be found to obtain here also. These instances certainly seem to indicate rather a transformation of organs than any totally distinct productions, a view indeed which is not at variance with the possibility of the transformed organs, being an indication of sexual functions, if we may be allowed to form any inference from known analogies in the animal world. Dr. Hooker, when examining the fruit of Laminariæ on his return from the antarctic expedition, felt convinced of the possibility of the transformation of an ascus into a spore, a view entertained long since by Fries, and which is supported by those instances in fungi and lichens where a single spore only is developed in an ascus. The difference in the analysis of the genus *Sphærophoron*, as given by Dr. Montagne in the 'Annales des Sciences Naturelles,' and by Dr. Hooker in the 'Antarctic Flora,' is probably due to a similar change; the former exhibiting true asci containing sporidia, the latter moniliform threads, breaking up into spores.. In earlier times the analysis of one would have been pronounced erroneous, but the present age, with deeper knowledge of the apparent anomalies exhibited by Nature, and consequently a greater measure of diffidence, regards such discrepancies as calls to further investigations, and as the possibly available keys for the solution of difficulties which have been hitherto insurmountable.

On a Monstrosity of Lathyrus odoratus. *By* Edwin Lankester, *M.D., F.R.S.*

This specimen was presented to the Section by John King, Esq., of Ipswich, in whose garden it had grown. The papilionaceous petals were reduced to mere scales, and the calyx assumed a less developed and perfectly regular form. The stamens were no longer diadelphous, but regular, 10 in number, and arranged in two rows. The carpels were reduced to the condition of a single leaf, on which were seated rudimentary ovules. The leaves and branches were not so large or expanded as is usual with healthy specimens of this plant.

On the Theory of the Formation of Wood and the Descent of the Sap in Plants. By Edwin Lankester, *M.D., F.R.S.*

The author drew attention to the theory of the formation of wood in plants, and objected to the view that the leaves form the wood, on the ground that the ligneous, like all other tissues, were the result of the growth of cells, which were not formed in the leaves; but wood was formed in all parts of the plant where elongated cells were generated, quite independently of leaves or the formation of leaves; as in the lower part of the cut wounds of the stems of plants, in the portions of trunks left when trees were cut down, in the abortive branches formed in the bark of such trees as the elm and the cedar, and in the other parts of the vegetable structure. He also objected to the theory of the formation of the ligneous, or any other secretion, which might be subsequently appropriated by the cells, in the leaves alone. He maintained that all the facts brought forward to support the theory of the descent of the sap might be explained on the known fact of the ready permeability of the tissues of the plant. He related the details of experiments performed on the species of spurge, in which the fluid was found to exude from the stem and branches in these plants just in proportion to the quantity of fluid contained in the plants above or below the section made. The cells of plants were nourished in two ways:—first, by the sap containing carbonic acid, ammonia, and other substances; and secondly, by materials, as sugar, gum, &c., formed in the cells. These latter were not formed solely in the leaves, but in all cells. He regarded the leaves as organs by which the water of the sap was got rid of, and by this means a further supply of sap from the earth and atmosphere was ensured. This function was performed in subservience to changes which were attributed to a specific vitality. It was unphilosophical to speak of vitality as a force when it could not be demonstrated to exist, and especially when physical forces were capable of explaining the phænomena.

Notes on the Botanical Geography of part of the Himalaya and Tibet. By Major E. Madden *and* Captain R. Strachey, *Bengal Engineers.*

This paper was illustrated by a sectional drawing of the Himalaya mountains, from the plains of India to Tibet, passing through the British province of Kumáon, on which the names of the more striking plants were inserted at the elevations where they were found. The section commencing from the southern face of the mountains first represented the band of forest that skirts their foot, chiefly composed of the trees of tropical India. Ascending, we find forms of temperate climates gradually introduced above 3000 feet,—*Pinus*, *Rosa*. *Rubus*, *Oak*, *Berberis*, *Primula*, &c. At 5000 feet the arboreous vegetation of the plains is altogether superseded by such trees as Oak, Rhododendron, Andromeda, Cypress and Pine. The first ridge crossed, ascends to a height of 8700 feet in a distance of not more than 10 or 12 miles from the termination of the plains. The European character of the vegetation is here thoroughly established, and although specific identities are comparatively rare, the representative forms are most abundant. On a part of this ridge is found a Palm, that on some mountains, not far off, attains a height of 50 feet at an elevation of more than 8000 feet above the sea, where it is every year covered with snow. Passing onwards we enter a zone of less elevation which is comparatively devoid of wood, and is chiefly devoted to agriculture. The climate is not very dissimilar to that of Northern India, but not nearly so hot, and many species of tropical plants occur. Crossing another ridge, similar in its vegetation to that first mentioned, we descend into the valley of the Sarjie, one of

the rivers that penetrate at a very low level far into the interior, carrying with them a tropical vegetation into the heart of the mountains. This, however, is considerably modified by the height and by the greater humidity. We thus find Pines and Palms, Oaks and Maples, growing with the ordinary trees of the plains, and a similar confusion of the flora of the temperate and torrid zones holds with the shrubs and herbs. From this valley we pass into that of the Pindar, which we follow up from 7500 feet to its source in a glacier at 12,000 feet. From 7500 to 11,000 feet, the region of Alpine forest, the trees most common are Oak, Horse-chestnut, Elm, Maple, Pine, Yew, Hazel growing to a large tree, and many others. They often grow to a very large size, and the forest is usually far finer than in the lower mountains. At about 11,500 feet the forest ends; *Picea Webbiana* and *Betula Bhojpatra* being usually the last trees. Shrubs, however, continue in abundance for about 1000 feet more, at about 12,000 feet the vegetation becoming almost entirely herbaceous. On this southern face of the mountains the snow line is probably at about an elevation of 15,500 feet. The constant condensation of vapour on this face causing a very humid climate, the vegetation is very luxuriant, and the great riches of the Himalayan flora are found in this region. As we pass to the north of the great snowy peaks, we leave behind us this wet climate and enter a country that very soon becomes equally remarkable for its extreme aridity. In the valley of the Gori, into which we next pass at an elevation of 11,500 feet, we find that several Tibetan plants have appeared, the flora, however, having become very poor. The gorges that lead to the great passes into Tibet are almost devoid of vegetation. The highest dicotyledonous plant noticed on this route was at about 17,500 feet, probably a species of *Echinospermum*; an Urtica also is common at these heights. The snow line here recedes to 18,500 or 19,000. In Tibet itself, the vegetation is scanty in the extreme, consisting chiefly of *Caragana*, *Artemisiæ*, *Astragali*, a few *Gramineæ*, *Potentilleæ*, &c. The plain to the north of the Himalaya is almost a desert, not more than one-twentieth of the surface being clothed with vegetation, and that of the most miserable sort, the bushes seldom rising above a foot in height. The cultivation of barley extends to a height of 14,000 feet. Vegetation ends at about 17,500 feet, the highest plants being Corydalis, Cruciferæ, Nepeta, Sedum, and some few others.

On the Botanical Geography of Western Tibet. *By* THOMAS THOMSON, *M.D., F.L.S.*

A section of this country, similar to that which accompanied Capt. Strachey's paper, was also exhibited. It extended on a line nearly north and south from the upper part of the Chenab river to the Kára Korum pass on the Konelun chain of Humboldt. The chain to the south of the Chenab, rising to an elevation of 15,000 feet, excludes a considerable quantity of humidity from the valley of that river, and the vegetation, though not altogether losing its truly Himalayan character, becomes much modified. Thus the Oaks, Rhododendrons, and Andromeda, so common on the southern mountains, are not found; while fruit-trees become more abundant, and the Grape-vine ripens its fruit admirably. Passing to the north, the next ridge that is crossed reaches a height of from 20,000 to 22,000 feet, the passes being usually upwards of 18,000 feet in elevation. To the north of this range the climate and vegetation suddenly change, and the Tibetan types are at once established. The general character of the Flora is Europeo-Siberian, but much modified by the extreme aridity which almost excludes trees and shrubs; it hardly exceeds 500 or 600 species in all. The chief groups are Boragineæ, Chenopodiaceæ, Cruciferæ, Astragaline Leguminosæ, and Artemisoid Compositæ. The few trees consist of a Poplar, confined to the more sheltered ravines, and an occasional Juniper on the hill sides. The more common shrubs are *Lonicera*, *Tamarix*, *Myricaria* and *Hippophaë*. The high Alpine herbaceous flora is almost strictly Siberian, and is a little more varied and copious than in other parts of this region, from the additional moisture derived from the melting of the snow. It extends sometimes even to a height of 18,500 feet.

ZOOLOGY.

Descriptions of two New Species of Nudibranchiate Mollusca, one of them forming the type of a New Genus. By JOSHUA ALDER *and* ALBANY HANCOCK. *With the Anatomy of the Genus, by* ALBANY HANCOCK.

The Mollusks described were found at Falmouth by W. P. Cocks, Esq. The first species noticed belongs to the rare genus *Thecacera*, of which only one species has been before described. The authors have named it *Thecacera virescens*, and characterize it as follows:—

T. virescens. Body rather convex, smooth, of a light peach-blossom tint, blotched with green anteriorly and posteriorly. Head with a plain subvelar margin in front. Tentacles broadly laminated, retractile within sheaths with plain margins. Branchial plumes five, green margined with white. A single row of obsolete tubercles encircles the branchial region. Length $\frac{3}{10}$ths of an inch.

The next mollusk described belongs to the family *Eolididæ*, and constitutes a new genus in that family, differing from *Eolis* in the position of the tentacles, and in having a subdorsal anus, and a curious frilled membrane down the side of each branchial papilla. It is thus characterized:—

Oithona, n. g. Body elongated, limaciform. Head with four linear tentacles constituting two pairs, both subdorsal. Mouth with corneous jaws. Branchiæ papillary, clothing irregularly a subpallial expansion on the sides of the back; a produced membranous margin or fringe runs down the inner side of each papilla. Anus laterodorsal, situated towards the right side. Orifices of the generative organs separate.

The species is named *O. nobilis*. It is of a pale buff colour, with the branchiæ of a rich brown, their apices having a metallic lustre.

The anatomy of the genus is given in detail by Mr. Albany Hancock. It corresponds with that of *Eolis* in its general features, but shows some very curious and interesting modifications; the most remarkable of which is the great development of the efferent or branchio-cardiac vessels of the vascular system. These vessels, which lie entirely within the skin, are conspicuous from the outside and show many ramifications passing into a large vessel which occupies the centre of the back behind the heart. A small but very distinct vessel, in connexion with them, runs down the frilled membranes of the papillæ, showing the branchial character of these organs. Another peculiarity of this animal is found in the hepatic apparatus. The pyloric extremity of the stomach receives two biliary ducts, one on each side of the intestine. These, diverging as they leave the stomach, pass into the skin at the sides of the back, where each opens into a wide hepatic channel that extends nearly the whole length of the body, receiving branches from the glands of the papillæ, &c. The anterior portion of the great hepatic channels are apparently connected with two folliculated glandular bodies, much and irregularly sacculated; and amidst the cellular tissue at the posterior part of the body there is likewise a glandular substance, folliculated and apparently branched, in connexion with the hepatic canals within the skin. This arrangement differs from that which prevails in the *Eolididæ*, in nearly all the genera of which the principal hepatic canals lie free in the visceral cavity, and there is a medial posterior trunk. In this genus there is no such trunk, and the canals are almost entirely within the skin. In this respect *Oithona* resembles *Hermæa*, but the peculiarities of the digestive system alone distinguish it from that genus as well as from every other member of the family.

On the Branchial Currents of Pholas *and* Mya. *By* JOSHUA ALDER *and* ALBANY HANCOCK.

The existence of branchial currents in the Bivalve Mollusca, received and discharged by different apertures, is now pretty generally admitted; but exception has been claimed for some genera and families whose anatomical structure is supposed to present an insuperable obstacle to this arrangement; their siphons, as it is thought, having no communication internally. Amongst these are the *Myadæ* and the *Pholadidæ*.

Mr. Garner, in his excellent essay on the Anatomy of the *Lamellibranchiata*, takes

this view of the case, and Mr. Clark, who has endeavoured to disprove the existence of separate branchial currents in all the bivalves, has more recently entered into many details of experiments to show that no internal communication exists between the two siphons of the genus *Pholas*.

That the *Pholades* and *Myadæ*, as well as other bivalves, do draw in a current of water by the branchial siphon, which is expelled by the anal one, the authors of this paper have long known from actual observation, confirmed by recent investigations; but to answer the objections raised on anatomical grounds, they have found it necessary to examine the internal structure of these animals with greater care than they had hitherto done. The result has been highly satisfactory, not only proving the existence of an internal communication between the siphons, but opening out new views of branchial action and its subserviency to the sustentation of the animal. The communication is found to take place through minute apertures between the meshes of the gills themselves. Each of the gill-plates or branchial leaflets consists of two laminæ united at the ventral margin, and likewise attached to each other in transverse lines running across the gills throughout their whole extent, and forming in the interspaces a series of parallel tubes which open into the anal or dorsal chamber, and are thus in communication with the excurrent siphon. The minute reticulated blood-vessels of the branchial laminæ, forming the walls of these tubes, are found when examined by a high power of the microscope to be open between the meshes, which are minutely ciliated, allowing the passage of the water into the tubes and from thence into the anal chamber. The gill-laminæ thus act like a sieve, not only aërating the branchial vessels most completely, but also straining the water, by which means the nutritive particles suspended in it are left on the outer surface of the gill, and by means of vibratory cilia are conveyed to the ventral margin, and thence along a marginal groove to the mouth. By laying open a living *Pholas* and colouring the water with indigo, the whole of this apparatus may be seen in action, which certainly forms one of the most beautifully adapted organic mechanisms that can be looked upon. As a breathing organ it is very complete; as a prehensile organ for receiving food, it is unrivalled for the minuteness and beauty of its structure.

An examination of the branchiæ of *Mya*, *Pullastra*, *Cardium*, *Ostrea*, and *Mytilus*, shows them to be formed after the same plan, and induces the authors to believe that the sieve-like character of the branchiæ and the mode of action here described predominate throughout the whole order of the *Lamellibranchiata* as well as in that of *Tunicata*, whose branchiæ are known to have a similar structure.

On Sea Sickness, and a New Remedy for its Prevention. By J. Atkinson.

The writer alluded to the method of curing sea-sickness proposed by M. F. Curie in the 'Comptes Rendus' of the French Academy of Sciences, September 30th, 1850, which consists of drawing in the breath as the vessel descends and exhaling as it ascends on the billows,—being based on the supposition that the complaint arises from the upward and downward movements of the diaphragm acting on the phrenetic nerves in an unusual manner. After remarking on various motions, as those produced by swinging and by riding in a carriage, by which nausea is often induced, and showing that voluntary operations performed by mechanics and labourers involving the same kind of movements of the diaphragm, &c. do not cause similar unpleasant results, he proceeded to detail the method which he had found successful in preventing sea-sickness, as follows:—

"Let a person on ship-board, when the vessel is bounding over the waves, seat himself, and take hold of a tumbler nearly filled with water or other liquid, and at the same time make an effort to prevent the liquid from running over, by keeping the mouth of the glass horizontal, or nearly so. When doing this, from the motion of the vessel, his hand and arm will seem to be drawn into different positions, as if the glass were attracted by a powerful magnet. Continuing his efforts to keep the mouth of the glass horizontal, let him *allow* his hand, arm and body to go through the various movements,—as those observed in sawing, planing, pumping, throwing a quoit, &c.—which they will be impelled, without fatigue, almost irresistibly to perform, and he will find that this has the effect of preventing the giddiness and nausea that the rolling and tossing of the vessel have a tendency to produce in inexperienced

voyagers." If the person is suffering from sickness at the commencement of his experiment, as soon as he grasps the glass of liquid in his hand and suffers his arm to take its course, and go through the movements alluded to, he feels as if he were performing them of his own free-will, and the nausea abates immediately, and very soon ceases entirely, and does not return so long as he suffers his arm and body to assume the postures into which they *seem* to be drawn. Should he however resist the free course of his hand, he instantly feels a thrill of pain of a peculiarly stunning kind, shoot through his head, and experiences a sense of dizziness and returning nausea. From this last circumstance, the author of the paper infers it as probable that the stomach is primarily affected through the cerebral mass, rather than through a disturbance of the thoracic and abdominal viscera; and he is of opinion that the method of preventing sea-sickness just described (which he has found by experience to be effectual), depends on the curious fact that the involuntary motion communicated to the body by the rolling and tossing of the vessel is, by the means he adopts, apparently converted into voluntary motion.

Drawings of New Species of Zoophytes were exhibited by Mr. Busk.

On some Indications of the Molluscous Fauna of the Azores and St. Helena. By Professor E. Forbes, *F.R.S.*

Great interest attaches to the malacology of the islands of the Atlantic, on account of its bearing on inquiries into the ancient conformation of land in that region, and the causes of the distribution of organized beings. We have so few data respecting the Invertebrata of the Azores and St. Helena, that every fragment of fresh information becomes of consequence. The author has lately had opportunities of examining a small collection of land shells gathered in the Azores by Mr. Macgillivray, the indefatigable naturalist, who accompanied the surveying voyage of H.M.S. Rattlesnake, and also a small parcel of littoral and sublittoral mollusks collected at St. Michael's and sent to Mr. MacAndrew. From St. Helena he has recently received a quantity of the shells cast on the shore, and a few recent and subfossil land shells collected by Mr. Alexander, a student of King's College.

Out of eight species of land shells from Fayal in the Azores, one is a new form of *Bulimus*, allied to a Madeiran species; two are *Helix paupercula* and *Pupa ancorostoma*, both Madeiran; one is the *Helix barbula* of Charpentier, an Asturian and Gallician species; two, *Helix pisana* and *Bulimus ventricosus*, are widely distributed south and west European forms; two, *Helix aspersa* and *H. cellaria*, are cosmopolites, diffused probably owing to transportation by man.

Of the marine shells from St. Michael's, *Purpura hæmastoma*, *Haliotis tubercularis*, *Mitra fulva*, *Trochus Laugieri*, and *Triton* (*variegatum*), are characteristic Lusitanian species, ranging also through the Mediterranean. A *Littorina* is not European; it is the *Littorina striata* of Capt. King, a species remarkable for being common to the Azores, Madeira, the Cape de Verds, and the Guinea coast. A starfish, sent with the shells, is the common *Uraster spinosa* of Europe.

The shells brought by Mr. Alexander from St. Helena are equally interesting. To the six land shells already known he adds three, a *Succinea*, a *Bulimus*, and a *Helix*, the last representing, but very distinct from, the *Helix guerincaria* of Madeira.

Our knowledge of the marine shells of Madeira has hitherto been entirely due to Mr. Cuming, who during a brief visit to that island, dredged for a day there in 40 fathoms water, on a soft muddy bottom. The shells he obtained (and of which he has most liberally communicated his lists) belonged to the genera *Cardium*, *Cytherea*, *Mitra*, *Clavatula*, *Pleurotoma*, *Nassa*, *Scalaria*, *Eulima*, *Pyramidella*, *Trochus*, *Delphinula*, *Turritella*, *Natica*, *Bulla*, and *Hyalina*. The species have proved, so far as they have been examined, to be, as they seemed to Mr. Cuming at the time he captured them, all peculiar.

To these genera Mr. Alexander adds specimens of *Lucina*, *Donax*?, *Hipponyx*?, *Acmæa*, *Siphonaria*, *Fissurella*, *Gena*, *Marginella*, *Cypræa*, *Conus*, *Cassio*, *Columbella*, *Cerithium*, *Fossarus* and *Rissoa*. In the British Museum there is an unnamed *Littorina* from St. Helena, closely represented but distinct from the *Littorina striata* above alluded to.

Several of the above-named shells are too young for determination, others are decidedly new. The known species not peculiar are *Cassis testiculus*, *Cypræa lurida*, *spurca* and *moneta*, *Conus equinaceus*, var. *Krottii*, *Marginella miliacea*? and *Natica canrena*. The *Fossarus* is not the Senegal shell, but the *F. Cumingii*. Several of the above are common to the West Indies and Mediterranean.

The author infers from these facts that the coast-line, of the ancient land of which the Atlantic islands north of the line are fragments, had a trend indicated by the distribution of the *Littorina striata*, and that the ancient connexion of the Azores with the Lusitanian land on the one hand and Madeira on the other, as previously maintained by him, is supported strongly by these additional data. On the other hand, the facts concerning St. Helena indicate, as the indigenous vegetation of that island had previously done, that it had been insulated from a very ancient period, and had never been connected with the continent. At the same time the marine mollusks would seem to point to the submergence of a tract of land probably linking Africa with South America, before the elevation of St. Helena. Along the sea-coast of such a tract of land, the creatures common to the West Indian and Senegal seas might have been diffused.

On a New Testacean discovered during the Voyage of H.M.S. Rattlesnake. By Professor E. Forbes, *F.R.S.*

Among the collections made by Mr. Macgillivray is a new genus of Gasteropodous Mollusks, floaters in the manner of *Ianthina*, but having close affinities of shell, animal, and operculum with *Jeffreysia*. It appears to throw new light on the nature of *Macluria* and the so-called Palæozoic Littorinæ. Prof. Forbes proposes to name this curious shell *Macgillivraya*.

On a Sample of Blood containing Fat. By J. H. Gladstone, *Ph.D.*

The author detailed an examination of a sample of serum, which was quite white and opake from floating globules of a substance that was found to consist of a crystalline matter, apparently cholesterin, mixed with a much larger amount of non-crystallizable fat, readily saponified when boiled with alkali. The sample was given to Mr. Wrench, who exhausted 2 oz. 40 minims of the liquid by means of æther, and obtained from it 3·96 grs. of fat. The amount of fatty matter in the blood itself must of course have been larger, since that portion which had become entangled in the coagulated clot was not estimated.

The blood was taken from a patient suffering from symptoms of apoplexy. He recovered. The author could not find any account of fatty blood having been observed in this disease.

Observations on the Genus Sagitta. *By* Thomas H. Huxley, *F.R.S., Assistant-Surgeon R.N.*

Mr. Huxley made some observations upon the structure of the anomalous genus *Sagitta*, which has already been more than once a subject of discussion at the Meetings of the British Association. Mr. Huxley's statements essentially confirmed those of M. Krohn; the existence of a ciliated canal or oviduct in the outer part of the ovary being the only new fact of any importance brought forward. The very wide geographical distribution of *Sagitta* was alluded to, the animal having been found in all the seas through which H.M.S. Rattlesnake passed in her circumnavigatory voyage.

In discussing the zoological relations of *Sagitta*, Mr. Huxley's remarks were to the following effect:—*Sagitta* has been placed by some naturalists among the Mollusca, a view based upon certain apparent resemblances with the Heteropoda. These however are superficial; the buccal armature of *Sagitta*, for instance, is a widely different structure from the tongue of Firola, to which, when exserted, it may have a distant resemblance; the distinct striation of the muscular fibre, and the nature of the nervous system, equally separate *Sagitta* from the Mollusca.

There appears to be much more reason for placing this creature, as Krohn, Grube, and others have already done, upon the annulose side of the animal kingdom, but it is very difficult to say in what division of that subkingdom it may most naturally be

arranged. At first sight it seems to present equally strong affinities with four principal groups, viz.—1. the Nematoid worms; 2. the Annelida; 3. the Lernæan Crustacea; and 4. the Arachnida.

1. With the Nematoid worms it is allied by its general shape and habit, its want of distinct annulation, and remotely, by the armature of the mouth. But on the other hand, it differs widely from them in the nervous system, the sexual system, and the nature of the muscular tissue.

2. *Sagitta* has no small resemblance to certain Naiadæ, in which when young the anterior hook-like feet are directed forwards parallel to the mouth. It differs from them in the nature of its nervous system, which exhibits a concentration quite foreign to the annelid type, in the nature of the muscular tissue, and in the total absence of any water vascular system.

3. and 4. The real affinities of *Sagitta* are probably with one or other of these great divisions. The structure of the nervous and muscular system speaks strongly for this view, and the nature of the sexual system is not opposed to it, inasmuch as we have hermaphrodism among both the lowest Crustacea (Cirrhipedia) and the lowest Arachnida (Tardigrada).

The study of development can alone decide to which of these divisions *Sagitta* belongs; but until such study shall have demonstrated the contrary, Mr. Huxley stated his belief that *Sagitta* bears the same relation to the Tardigrada and Acaridæ, that Linguatula (as has been shown by Van Beneden) bears to the genus *Anchorella*, and that the young *Sagitta* will therefore very possibly be found to resemble one of the Tardigrada, the rudimentary feet with their hooks being subsequently thrown up to the region of the head, as they are in Linguatula.

An Account of Researches into the Anatomy of the Hydrostatic Acalephæ. By Thomas H. Huxley, *F.R.S., Assistant Surgeon R.N.*

The observations upon which this communication is based were made during the circumnavigatory voyage of H.M.S. Rattlesnake, but for the most part in the seas which border the coasts of North-eastern Australia, New Guinea, and the Louisiade archipelago.

With the exception of the mere external form, but very little has been known hitherto with regard to either the Diphydæ or the Physophoridæ, the two families of which the 'Hydrostatic Acalephæ' of Cuvier consist, although they are some of the most abundant of pelagic creatures. Indeed, hardly any one can have made a voyage to the East Indies or Australia without being struck with the immense shoals of the *Physalia* and *Velella*, through which the ship sometimes sails for days together.

The chief mass of one of the Diphydæ is formed by two transparent crystalline pieces, which look, when taken out of the water, like morsels of cut glass. One or both of these pieces contains a wide cavity, lined by a muscular membrane, by the contraction of which the animal is propelled through the water. The attachment of the posterior piece to the anterior is very slight, and when detached it will swim about independently for hours together. It was this circumstance which led Cuvier to consider the two pieces as two distinct animals.

In the Monogastric Diphydæ a single polype is developed in a special cavity of the anterior piece. In the Polygastric Diphydæ, a long chain of such polypes, each enveloped in a little transparent "bract," occupies a similar position. These polypes have no oral tentacles, but a long thread-like tentacle, bearing lateral branches, which are terminated by small sacs, is developed from the base of every polype. The small "prehensile" sac has a very peculiar form, but is, morphologically, only a dilatation of its pedicle, one wall of which is much thickened, and contains a great number of such urticating organs or "thread-cells" as are found among the Medusæ. The reproductive organs are medusiform bodies which are developed by gemmation from the pedicle of the polype.

The central sac of the medusiform body, instead of becoming a stomach, developes the spermatozoa or ova within its walls. These are generally shed forth while the organ is still attached, but in one genus they swim about independently, and might readily be mistaken for Medusæ.

In the Polygastric Diphydæ new polypes are continually being produced by gem-

mation at the attached extremity of the polype chain, and in both polygastric and monogastric forms, the same gemmation is continually going on among the prehensile and reproductive organs. The gemmæ, whether they are eventually to become polypes, prehensile organs, or reproductive organs, are invariably at first simple, double-walled processes, containing a cavity continuous with that of the common stem of the animal, which is itself a double-walled tube. The Diphydæ, whether polygastric or monogastric, are invariably diœcious.

The genus *Rosacea*, among the Polygastric Diphydæ, is remarkable in possessing only the anterior piece, which is gelatinous and hemispherical, like the umbrel of a *Medusa*. If a peculiar dilatation—the float—were formed at the extremity of the polype-chain of a Diphyes, we should have one of the Physophoridæ.

The genera *Rhizophysa*, *Physalia*, *Athorybia*, *Physophora*, *Stephanomia*, *Agalma*, *Porpita*, and *Velella*, were described and their structure illustrated by diagrams, without which the details would be unintelligible. Suffice it to say, that their forms, however varied, are shown to be simple modifications of a common type, in the main identical with that of the Diphydæ. Thus, such a polype-chain as that of *Rosacea*, if it developed a float, would be a *Rhizophysa*. The *Physalia* is a *Rhizophysa* with its float disproportionately enlarged; the *Physophora*, a *Rhizophysa* which has developed lateral natatorial organs like those of a Diphyes. Again, the *Velella* may be considered as a *Physalia* flattened out and having its air-sac divided and subdivided by partitions, until it becomes a firm, resisting, internal shell.

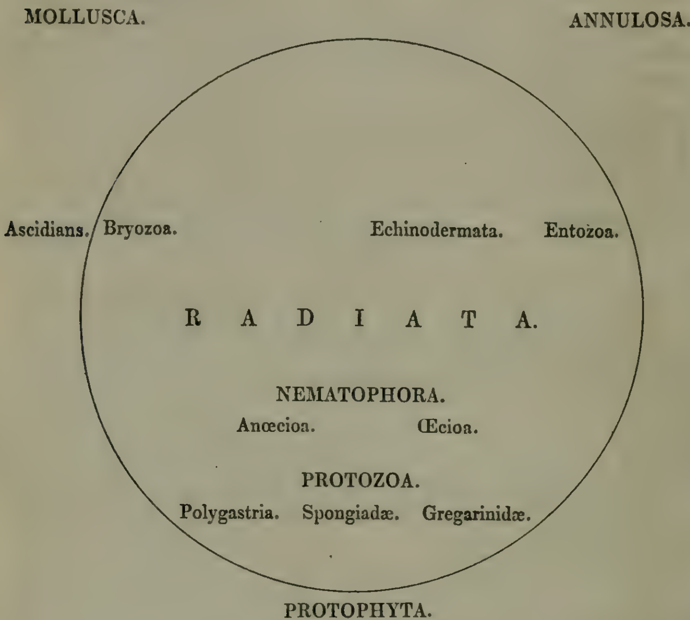
The same continual multiplication of parts by gemmation goes on among the Physophoridæ as among the Diphydæ; and the structure and mode of development of the young organs is essentially the same. Great variety is presented by the reproductive organs, from the form of mere sacs to that of free swimming bodies, precisely resembling Medusæ, and developing the generative elements only subsequently to their liberation. In *Physalia*, the female organs are free-swimming medusiform bodies, while the male organs are simple pyriform sacs, which remain attached and develope their spermatozoa *in situ*. In the language of the "alternation theory," the *Physalia* itself and the medusiform body would be two generations, and we should be presented with the unexampled peculiarity of a male giving birth to a female.

As a general conclusion, it may be stated that the Diphydæ and Physophoridæ are essentially composed of two membranes, an outer and an inner, which the author calls "foundation-membranes," since every organ is formed by the modelling into shape of one or other, or both of these, commencing as a simple process or diverticulum, and assuming its perfect form by a gradual differentiation. The stomach has no walls distinct from those of the general parietes. The reproductive organs are always developed externally, and the thread-cell is found in all in the greatest abundance. The author lays particular stress on the bearing of the latter fact upon classification, and shows that the same organ is met with in equal abundance only in the Hydroid and Sertularian Polypes, the Medusidæ, Beroidæ, and Anthozoic Polypes. A similar organ has indeed been also found in an Echinoderm, in certain Trematoda, and perhaps, although the author is inclined to think that its presence in this case is accidental, in Eolis; but in none does it assume such a prominent place as in the families mentioned.

The author endeavours to show that this fact, combined with the radiate polype form, and the composition of the body of two distinct membranes, forms a very good *positive* character for a group embracing the Hydroid and Anthozoic Polypes, and the Acalephæ; a group equal in importance to any one of the primary subdivisions of the animal kingdom. The name of *Nematophora*, "thread-bearers," is proposed for this group, in allusion to the characteristic diffusion of the "*thread*-cell." But this group must be subdivided into two equivalent sub-classes. In the Hydroid Polypes, the Diphydæ, Physophoridæ, and Medusidæ, the stomach is *not distinct* from the common parietes, and the reproductive organs are *external*. In the Anthozoic Polypes and Beroidæ, the stomach *is distinct* from the common parietes, and the reproductive organs are *internal*. Some years ago Mr. W. S. MacLeay, when consulted by the author, suggested the name of *Œcioa* (those which have their eggs under cover, "housed") for the latter division, and that of *Anœcioa* for the former. Now a mutual representation runs through these two groups. For instance, the Actinidæ represent the Hydra and its allies; the Zoanthidæ represent the Corynidæ; the Physophoridæ seem to represent the Pennatulidæ; and the Medusidæ, the Beroidæ.

Furthermore, each group returns into itself; the free floating Actiniæ nearly approximate Beröe, and *Lucernaria* is but a fixed *Medusa*.

Should these considerations eventually prove to be well-founded, the author considers that it will be necessary to break up the class Radiata of Cuvier into four groups, severally capable of being defined by positive characters. Supposing the Nematophora to form a sort of central group, we have on the one hand the Ascidians and the Bryozoa, leading to the Mollusca; on the other the Echinoderms and Entozoa (in the widest sense), leading to the Annulosa; whilst the Polygastria, Sponges, and Gregarinidæ (if indeed they are not rather to be considered only as the lowest forms of the other three groups) conduct us towards the lowest plants. These relations may be thus represented:—



Description of a New Form of Sponge-like Animal. *By* T. H. Huxley, *F.R.S.*

The author described a gelatinous substance found in almost all seas, in masses varying in size from that of a pea to that of a walnut. This mass is an animal of extreme simplicity, analogous to the Palmellæ in the vegetable kingdom, and consisting of a number of simple cells united by a gelatinous connecting matter, containing siliceous spicula.

The author pointed out the importance of this creature as connecting the *Spongiæ Gregarinidæ* and *Polythalamata*.

On the Land and Freshwater Mollusca found within seven miles of Nottingham. *By* E. J. Lowe, *F.R.A.S.*

1st. Land Shells (*Univalves*).

Azeca tridens, rare at Highfield House.
Arion ater and *A. hortensis*, common.
Achatina acicula, rare at Ratcliffe.

Balea perversa, rare at Thrumpton.

Bulimus lubricus, common; *B. obscurus*, common at Highfield House and Nottingham Castle, but has not been found elsewhere.

Carychium minimum, common.

Clausilia nigricans, common.

Limax agrestis, *L. carinatus*, *L. flavus* and *L. maximus*, common.

Vertigo pusilla, rare at Highfield House.

Helix aspersa, *H. nemoralis*, common; var. *hortensis*, rare at Bulwell; var. *hybrida*, rare at Highfield House; *H. pulchella*, abundant; var. *crenella*, rare at Highfield House; *H. hispida*, common; var. *concinna*, at Highfield House; var. *depilata*, at Highfield House; *H. rotundata*, common; *H. cellaria*, common; *H. arbustorum*, at Thrumpton; *H. fulva*, at Thrumpton, Highfield House, and Stanton on the Wolds; *H. virgata*, rare at Highfield House; *H. ericetorum*, very abundant at Stanton on the Wolds, I have not found it elsewhere; *H. alliaria*, at Sawley and Thrumpton, at the former place very abundant; *H. aculeata*, rare at Highfield House and Stanton on the Wolds; *H. caperata*, in extraordinary numbers at Stanton on the Wolds, but not found elsewhere; *H. crystallina*, Highfield House, Bulwell, and Oxton; *H. nitidula*, rare at Bulwell and Oxton; *H. radiatula*, at Highfield House; *H. granulata*, rare at Bulwell; *H. lucida*, uncommon at Bulwell, Oxton, Stanton and Highfield House; *H. pura*, rare at Oxton; *H. pygmæa*, rare at Highfield House and Stanton; *H. sericea*, rare at Bulwell, Oxton, and Stanton; *H. revelata*, rare at Stanton on the Wolds. This is the first time it has been found in England.

Pupa umbilicata, common.

Vitrina pellucida, common. Forty species.

2nd. Mud and Water Shells (*Univalves*).

Bithinia ventricosa (Forbes), common; *B. Leachii*, rare at Lenton and in Nottingham Meadows.

Limnea auricularis, *L. peregra*, *L. stagnalis*, *L. palustris*, *L. truncatulus*, all abundant; *L. glaber*, rare at Bulwell.

Neritina fluviatilis, common in Trent, found in River Soar.

Paludina vivipara (Forbes), common.

Patella fluviatilis, common; *P. lacustris*, uncommon, at Lenton and Nottingham Meadows.

Physa fontinalis, common; var. *acuta*, common; *P. hypnorum*, at Beeston and Nottingham Meadows; *Amphipeplea glutinosa*, at Beeston Ryelands.

Planorbis corneus, *P. carinatus*, *P. marginatus*, *P. vortex*, and *P. spirorbis*, common; *P. albus*, in Trent; *P. contortus*, Bulwell and Lenton; *P. imbricatus*, Highfield House; *P. nitidus*, rare at Highfield House and Wollaton.

Succinea putris, common at Thrumpton; *S. Pfeifferi*, common.

Valvata piscinalis, common; *V. cristata*, Bulwell and Beeston. Twenty-eight species.

3rd. Water Shells (*Bivalves*).

Anodon cygneus, common; var. *anatina*, common; var. *cellensis*, common; var. *ventricosa*, at Highfield House; var. *Avonensis*, rare in River Trent.

Cyclas rivicola, *C. cornea*, *C. lacustris*, common.

Dreissena polymorpha, common.

Pisidium Henslowianum, rare at Highfield House; *P. amnicum*, common; *P. cinereum* and *P. nitidum*, at Clumber; *P. obtusale*, *P. pulchellum* and *P. pusillum*, at Beeston.

Unio pictorum, *U. tumidus*, var. *U. ovalis*, common. Sixteen species.

On the Antennæ of the Annulosa, and their Homology in the Macrourals. *By* Dr. W. Macdonald, *F.R.S.E.*

On some recent Calcareous Zoophytes found at Ipswich, Harwich, &c. *By* C. W. Peach.

Seeing no calcareous zoophytes in the museum at Ipswich, and having found 15 or 16 species at that place, some from the Orwell, others from Harwich, the author mentioned them to induce some one to collect and supply the defects in the museum.

Some of the specimens found are the most beautiful of the British Lepralias, one new to the British list, found also by him in Cornwall and Scotland; he also produced one new to the British list from Cornwall, identical with a Lepralia on a Pinna from the Mediterranean.

He also called attention to the scooping of pits in shells and stones by Lipralia and other calcareous zoophytes, and exhibited several specimens of shells and a stone which had been scooped by one of the most delicate of them, *Hippothoa divaricata,* which it had equally scooped with those of larger size. Some of the shells had not only the pits, but the cells of *Lepralia* as well.

Observations on the Geographical Distribution of the Land Mollusca. By LOVELL REEVE, *F.L.S.*

This paper consisted of a few additional observations on the geographical distribution over the globe of a tribe of snails, recently published by Mr. Reeve in the 'Annals and Magazine of Natural History.' It was doubted at the time whether a system of typical arrangement could be formed upon the consideration of a single genus,—whether an examination of all the genera of land mollusca was not essential. It being a work of considerable labour to collect the data for this inquiry, the author submitted a preliminary outline of his views from a consideration of 500 *Bulimi* only. He was now working upon the genus *Helix*, and found the results to be perfectly similar. The inquiry was founded on a consideration of the shell, not on account of the difficulty of procuring observations on the animal, but because it offered a readier and more varied set of characters. The animal differs immaterially in form and generic character from any of the genera of land mollusca, but the shell varies according to the physical conditions by which it is surrounded. The groups of forms appear to be so many expressions of the calcifying organ of one and the same mollusk, depending on the laws and circumstances of organic distribution. On comparing his map of the distribution of land mollusca with that of the marine mollusca by Professor E. Forbes, Mr. Reeve pointed out many points of resemblance where the areas of sea distribution of types corresponded with those on the adjacent land.

Observations on Pholas. By J. ROBERTSON.

On the Structure of the Branchiæ and Mechanism of Breathing in the Pholades and other Lamellibranchiate Mollusks. By THOMAS WILLIAMS, *M.D.*

The researches of the author, which were illustrated by numerous diagrams, had led him to the following conclusions:—

1. That the blood in all lamellibranchiate mollusca is richly corpusculated.
2. That the branchiæ in all species are composed of straight parallel vessels returning upon themselves.
3. That the heart is systemic, and not branchial.
4. That the parallel vessels of the gills are provided with vibratile cilia disposed in linear series on either side of the branchial vessel, causing currents, which set in the direction of the current of the blood in the vessels.
5. That in *Pholas* the siphons are richly lined with vibratile cilia as well as the branchiæ.
6. That the branchial siphon acts in drawing in water into the chamber of the mantle by the diastole of the valves of the shell.

That a part of the water which is thus drawn into the branchial chamber, is swallowed and eventually rejected by the fæcal orifice, and that the rest is expelled by the orifice in the mantle, the foot, and in part by the branchial orifice.

That this respiratory fluid is surcharged with carbonic acid and fluid secretions contained in the mucus furnished by the interior of the mantle.

That this current, escaping with force against the walls of the cell in which the animal lives, acts as a solvent upon the particles disintegrated by the action of the valves; that therefore the boring of the Pholades can only be explained on the principle that a chemical as well as a mechanical agency is at work.

PHYSIOLOGY.

On a New Apparatus for supplying Warm Air to the Lungs. By T. G. HAKE, *M.D.*

On the Correlation of Vitality and Mind with the Physical Forces. By RICHARD FOWLER, *M.D., F.R.S.*

The author began his paper with some observations of what constitutes force. Our notions of it, he thinks, are acquired very early, from feelings of resistance to our will; for all forces are measured by the resistance they can overcome, *i. e.* the force they can antagonize. When boys of apparently equal strength and equal courage are seen to wrestle, we are impressed with a belief that he who fairly throws the other has the most powerful muscular (vital) force; but when we see that a spirited boy of comparatively weaker muscular force cows and throws a larger boy of more muscular strength, we then infer that mind was the force in the boy who more than antagonized the vital force of the other. "What," asked Suwarrow, "is the strength of an army?" "The stomach!" was the answer of his experience; and the stomach, the source of vital strength, is furnished with its materials by the physical forces of motion, heat, and chemical affinities. Here then we have correlations of mind with the vitality of its coil, and of vitality with the physical forces. Mind and vitality have these analogies with the physical forces:—1st, That all act through the media of coils; 2nd, that the manifestation of the force is directly as the fitness of the coil, and that wherever an appropriate coil is presented, there the force will be apparent to our senses. The chronometer as the measurer of time by space, the voltaic trough and the coil of Œrsted, and the heat and light from the spontaneous union of hydrogen and oxygen in spongy platina, are satisfactory instances.

The cretin affords an analogous instance with respect to the vital and mental forces. Born with a corporeal coil fitted for both, their manifestation gradually becomes obscure as the body is diseased; but when again restored by the invigorating air, exercise, food, and social converse of a mountain home, the forces of mind and vitality reappear: here, is it not mind which devised the reparation of the mortal coil in the case of the cretin, and which has devised the coils which vitality has materialized for all the physical forces? Had then minds of the highest order been withheld, the physical forces had wanted the coils by which they are now rendered so effective; and if the physical forces had remained latent, the seed of plants and ova of animals could not have become coils fitted for the activity of vitality and mind.

Correlation of the Organs of Sense.—That these might be indifferently the antecedent or sequent of each other's functions in effecting sensations or conceptions, occurred to the author while in the year 1792 he was preparing a paper on Belief, which he read to the Speculative Society of Edinburgh (see the History of the Society lately published). It is the law of our organs of sense that a sensation or conception in any one should excite a re-transmission to the adjusting muscles of all the other organs. The most palpable instance of an analogous re-transmission from one nerve to many muscles is from the nasal branch of the fifth pair in the act of sneezing.

Doubts have been expressed whether these forces may not be really distinct and independent forces, rather than modifications of one force, as conjectured by Mr. Grove. There are however several analogies in support of Mr. Grove's hypothesis. By the modification effected by glands differently constructed, secretion of varied qualities are produced from the blood; different fruits from the same sap, modified by grafts; one thought may be modified as in words that are synonymous, and both the thought and instinct of man or the lower animals are modified by their structure,—"Many administrations, but the same spirit." As therefore the force is more or less effective in ratio of its coil, and as coils for thinking or acting, in science, in arts, and in the ordinary business of life, are formed by the adjusting muscles of the sentient and voluntary functions of the body, is it not the business of education to drill the coils, by which alone elevation and efficiency can be given to the force of mind?

GEOGRAPHY AND ETHNOLOGY.

On the Origin and Institutions of the Cymri. *By* GEORGE BARBER BEAUMONT, *F.G.S.*

A Summary of Recent Nilotic Discovery. *By* C. T. BEKE, *Ph.D., F.R.G.S.**

After briefly recapitulating his views with regard to the physical character of the table-land of Eastern Africa, the position of the sources of the Nile in the Mountains of the Moon, and the course of the direct stream of that river and of its several tributaries, namely, the Bahr-el-Ghazal or Keïlak, the Sobat or Godjeb, the Bahr-el-Azrek or Astapus, and the Atbara or Astaboras, Dr. Beke adverted to the explorations of the Rev. Dr. Krapf and Mr. Rebmann in Eastern Africa, to their discovery of the Snowy Mountains Kilimandjaro and Kenia, and to the information obtained by them respecting the great lake in the country of Uniamezi, or Mono-Moezi. He then gave an account of Dr. Knoblecher's recent ascent of the Tubiri, as the direct stream of the Nile is called, as far as 4° 9′ N. lat., where he ascertained that that river comes from a considerable distance further south, and apparently from beyond the equator.

The distance from the extreme point reached by Dr. Knoblecher to Mount Kenia is 370 geographical miles, and to the lake in Uniamezi it is 360 miles; and the basin of the Nile is apparently confined within these limits, unless indeed the river should be found to flow out of the lake itself. Kenia is not improbably the "high mountain, the top of which is quite white," which was described to Baron von Müller as containing the source of the Bahr-el-Abyad.

These results are in general accordance with the statements of Ptolemy respecting the sources of the Nile in the Mountains of the Moon, as elucidated and explained by Dr. Beke on former occasions†.

Addition by the Author.—On a subsequent journey far into the interior, Dr. Krapf was informed that at the foot of the snowy mountain Ndurkenia, or Kirenia, is a lake, from which (or its vicinity) flow three rivers—the Dana, the Tumbiri, and the Nsaraddi; the first two of which fall into the Indian Ocean, being the upper courses of the Ozi and the Adi or Sabaki respectively, while the third flows northwards towards a still larger lake, called Baringo, being in Dr. Krapf's estimation identical with the Bahr-el-Abyad or White River.

This information tends yet further to confirm Dr. Beke's conclusions. And if it be only supposed that Dr. Krapf has inadvertently transposed the two names, Tumbiri and Nsaraddi, so that it is, in reality, the former which flows northwards and leaves the Nile, while it is the latter which falls into the Indian Ocean; then that traveller's *Tumbiri* will correspond with the *Tubiri* of M. Werve and Dr. Knoblecher, and his Nsar-*addi* with the *Adi* or Sabaki—a double coincidence rendering the matter little less than certain.—See *Athenæum* of February 14, 1852, No. 1268, p. 198.

On the Meteoric Iron of Atacama. *By* G. A. BOLLAERT.

Some of the blocks of meteoric iron found there were alleged by the natives to have risen or burst from the earth: they contained nickel and other metallic bases.

On certain Tribes of South America. *By* W. J. BOLLAERT.

A Comparison of Athletic Men of Great Britain with Greek Statues. *By* J. B. BRENT, *M.A.*

Mr. Brent began by stating the difficulty of arriving at an accurate average of the weights and measurements of the men of any given country. In order to obtain

* Printed *in extenso* in the Philosophical Magazine for October 1851, 4th series (No. 11), vol. ii. pp. 260–268.

† See Report of the British Association for 1846, Report of the Sections, pp. 70–72; and see Report for 1848, Report of the Sections, pp. 63, 64.

those of the athletæ, he measured and weighed celebrated boxers, cricketers, wrestlers, rowers, pedestrians and others. These he compared with the heights and weights of soldiers and policemen, and thence with certain celebrated Greek statues. From such a comparison it appears that the wrestlers of Cornwall, Devon and the north of England are not inferior to those statues.

Communication relative to the Great Earthquake experienced in Chile, April 2, 1851. By R. Budge, *F.R.G.S.: in a Letter to* Mr. W. Bollaert, *dated Apr.* 17, *with Observations by the latter.*

Mr. Budge states the motion to have been westward; water in basins, water-jugs, &c. having been spilt over the east side; clocks whose pendulums vibrated east and west having stopped, while those beating north and south did not; walls standing east and west being cracked every way, particularly lengthways; and vessels at sea, forty to sixty miles off the land, having felt it at an hour corresponding to the difference of longitude. The author supposes the phænomenon to have been subject to instantaneous cessations; and states that it turned round things on their base, instead of throwing them down, at an angle of 20°, showing a circular motion for at least an instant*. "I had a bust of plaster of Paris and a family medicine-chest standing on a chest of drawers moved round in this way, while nothing occurred to my house (built, however, purposely on my own plan for resisting earthquakes), except the removal out of place of a few tiles. A large brick chimney, well-stayed above with iron stays, was divided at a certain height from the ground in a horizontal line, and the upper part was twisted round over the lower to about the same angle. In some houses which stood firm from being frame-built, though cracked in all directions, the furniture in the rooms, particularly up stairs, appeared as if some fiend had been among them, making them his playthings, some upset, some turned round, &c."

The author proposed an explanation of these and other phænomena of earthquakes by electricity:—"I have experienced in this place, as I have stated, three ruinous earthquakes,—that of 1822, which I passed in the house until the back fell; that of 1829, and the present. On the last occasion the barometer and thermometer indicated nothing, nor was there the least warning of any description; but as invariably occurs after a heavy shock, we had on the third day after a shower of twelve hours' rain, for which I had already prepared, aware of its being the consequence, happen at whatever season it may. I conceive also, that I have felt less relaxed than before it. I cannot understand all these things unless electricity be the agent; while the atmosphere must be affected in some way to shower down rain at seasons when under ordinary circumstances it does not fall. Santiago (the capital of Chile), Casa Blanca, and Quillota seem to have suffered equally with Valparaiso; and the two latter places worse, while some of the public buildings of the capital are ordered to be pulled down. My wife, who is at that place, mentions every subsequent shock tallying exactly with those here. The shock of 1822 was, however, about double in force and time; and I recollect well it was with difficulty I could stand, whereas on the present occasion I had no trouble. On that occasion, the sea in the Bay of Valparaiso retired considerably, and was several days in reaching its former level, while on this no such thing was observed. It is an awful fact to contemplate, that the most massive buildings of the country are the first to yield to the phænomena referred to."

Mr. Bollaert observed:—"Sometimes the violent eruptions of volcanoes are accompanied by severe earthquakes; and in regard to those of Peru, I will instance one of this species, in which volcanic action was accompanied by a terrific earthquake, viz. the eruption in February 1600, in the mountain range of Ornate, twenty-two leagues from Arequipa. On the 15th of that month the volcano broke out with great fury and the ground was in continual motion. On the 18th, in the evening, the movements were more rapid, and at 10 P.M. there was such a shock that it awoke the soundest sleepers, and every five minutes during the night shocks

* Mr. Mallet has explained this torsion of objects, 'Report on Earthquakes,' Brit, Assoc. Reports, 1850.—Edit.

continued. On the morning of the 19th occurred a dreadful shock, of which the Spanish MS. from which I extract this says, 'the movements were now more rapid, and in the twenty-four hours there were more than 200 shocks. The heavens were darkened with clouds of eruptive matter, flashes of lightning were seen, and then there descended much white ashes like a fall of snow, which covered the country around.' On the 28th of the same month happened the most dreadful shock of all. The town of Quinistacas, four or five miles distant from the volcano with 100 inhabitants, was buried; the town of Ornate also perished; also many villages in the vicinity were ruined; indeed, the whole country was desolated, and ashes fell more than ninety miles distant from the volcano. The first earthquake I experienced was in 1825 and at Chile. There was a shaking of the ground, some houses and walls fell down, and the water in the (arequias or) water-courses splashed over. I was also in that of 1829, being in Santiago. The commotion commenced on Saturday the 26th of September at twenty minutes past 2 P.M. The principal undulations appeared to come from the south-east. The great shock was 1½ minute duration. Half an hour afterwards there was a shower of rain, and another slight shower at half-past 4 P.M. The weather, however, before the earthquake was rather inclined for rain. During the night of the 26th there were slight shocks; also some on the following days, Sunday and Monday. On Friday the 1st of October, at half-past 12, there was another shock, as well as at half-past 1. I went out into the street and found the inhabitants looking at two volcanoes that had broken out, one in the Dehsa, behind the first range of the Cordillera; the other in the mountains of Maipu (which last was observed to be in activity just after the earthquake of the 26th), the smoke rising majestically. In Peru I have felt many, but not very heavy ones. In the province of Tarapaca, lat. 20° south, I have noticed them as occurring two or three times a month, sometimes accompanied by a slight rumbling noise which appeared to be subterraneous. But on one occasion, being in the silver mines of Guantajaya, a few miles east of the port of Iquique in the province of Tarapaca (these mines are from 2000 to 3000 feet above the sea), at about 100 yards perpendicular depth in the mine a slight rumbling noise was heard, as if coming from the Andes, which increased and then passed onwards to the west; the noise was immediately followed by a horizontal undulatory movement, then a vertical, then a mixture of these, or a shake, and then all was quiet, save a commotion occasioned by some of the loose stones of the mine rolling downwards. My impression then was, and still continues, that earthquakes in the region under discussion (Peru and Chili) originate from volcanic causes. A great part of the Andes is volcanic; Chile abounds in active and quiescent volcanoes; and in the province of Tarapaca there are the volcano of Isluga, with its five craters, the *Volcancitos* or water volcanoes of Puchuttisa,—doubtless many quiescent ones,—on its northern boundary the volcanic group of Gualtieri, and on its southern the volcanoes of Laguna, Olea, &c."

On the Negro Races of the Indian Archipelago and Pacific Islands. *By* W. John Crawfurd, *F.R.S.*

Oriental negroes are found thinly but widely scattered from the Andaman islands in about 80° of E. longitude, to the New Hebrides in the Pacific, in about 175° E. longitude; and from the Philippine islands in 18° N. latitude, to New Caledonia in about 21° S. latitude. These eastern negroes are known to Europeans under various names. The Malays term the inhabitants of New Guinea Papua, or more correctly Pua-pua. Europeans, taking this as an authority, call New Guinea and its inhabitants both Papua.

The word *pua-pua* is an adjective and signifies crisp, frizzled, woolly. To complete the sense for the country or people, it is necessary to state the nouns-substantive, *tanah* = country, and *oran* = people. Thus *oran pua-pua* = a woolly-headed man; and *tanah oran pua-pua* = the land of woolly-headed men.

European writers have also sometimes termed them Alfores; which word has been converted by English and French writers into Arafura and Harafura, and referred to a Malay source. It is not, however, Malay, because the letter F is not to be found in any written language of the Indian archipelago, and seldom does the sound occur in any of the unwritten ones. The word is Portuguese, and means

freedman, in which sense it is adopted by the natives of the country. It is nearly equivalent to the *Indios bravos* of the Spaniards, as they term the free unsubjugated Indians of Spanish America.

Spanish writers term the negroes of the Philippine islands, from their diminutive size, *Negritos*, or little negroes. Some English writers have lately termed them Austral negroes, which is manifestly improper, since they are found equally in the northern as in the southern hemisphere; and this even in the islands of the Indian archipelago.

The oriental negro is ever found in a state of civilization below that of the brown-complexioned and lank-haired race in their neighbourhood, whether these be Malayan or Polynesian. There is great diversity in their civilization; some, with the least possible knowledge of the commonest arts of life, live precariously on the spontaneous produce of their forests and waters, both animal and vegetable; while others practise a rude husbandry, construct boats, and undertake coasting voyages for the fishing of the tortoise and tripang or holothurion.

The negro of the Andaman islands is below five feet in stature, and is of the lowest civilization. The negro of the northern portion of the Malay peninsula is also of short stature. A full-grown male of average height was found to measure only four feet nine inches. The negro of the Philippine islands, found chiefly on the large island of Lucon, is also diminutive. They dwell in the mountains, generally maintain their independence, and live in constant warfare with the Malays.

There are no negroes in Sumatra, Java, Borneo and Celebez, nor is there any record or tradition of any. The great island of New Guinea is almost wholly peopled by negroes, who differ from each other, and more so from those distinct races described as existing in the Andaman islands, in the northern parts of the Malay peninsula and in Lucon.

M. Modera, an officer of the Dutch navy, has described two negro tribes which exist on the west coast of New Guinea. After describing one of these tribes, he says,—"In the afternoon of the same day, at the time of high water, three of the naturalists went in a boat well-armed to the same spot, where they found the trees full of natives of both sexes, who sprang from branch to branch with their weapons on their backs, like monkeys, making similar gestures and screaming and laughing as in the morning. And no offers of presents could induce them to descend from the trees to renew the intercourse*."

The most singular physical character of the negro of New Guinea consists in the texture of the hair of the head. It is neither that of the negro of Africa, nor seemingly that of the oriental negro north of the equator. Mr. Earl, who has seen most of the negro tribes of New Guinea, and who best describes them, gives the following account of it:—"The most striking peculiarity of the oriental negro," says he, "consists in their frizzled or woolly hair. This, however, does not spread over the surface of the head, as is usual with the negroes of western Africa, but grows in small tufts, the hairs which form each tuft keeping separate from the rest, and twisting round each other, until, if allowed to grow, they form a spiral ringlet. Many of the tribes, especially those which occupy the interior parts of islands whose coasts are occupied by more civilized races, from whom cutting instruments can be obtained, keep the hair closely cropped. The tufts then assume the form of little knobs about the size of a large pea, giving the head a very singular appearance, which has not inaptly been compared to that of an old worn-out shoe-brush. Others, again, more especially the natives of the south coast of New Guinea and the islands of Torres Straits, troubled with such an obstinate description of hair, yet admiring the ringlets as a head-dress, cut them off, and twist them into matted skull-caps, thus forming very compact wigs. But it is among the natives of the north coast of New Guinea and of some of the adjacent islands of the Pacific that the hair receives the greatest attention. These open out the ringlets by means of a bamboo comb shaped like an eel-spear, with numerous prongs spreading out laterally, which operation produces an enormous bushy head of hair, which has procured them the name of mop-headed Indians."

There are fifteen different varieties of oriental negroes, of eleven of which we have

* Mr. Windsor Earl on the Papuan Indians, Journal of Indian Archipelago, vol. iv. p. 1.

good descriptions. Some of them are feeble dwarfs under five feet, and others are powerful men. To include the whole under one category is surely contrary to truth and nature.

As far as language can be considered a test of race, and as the present state of our knowledge on the subject will enable us to judge, it goes to prove that all the races of whose languages we possess examples, are separate and distinct from each other. I have compared the words of nine negro languages. Three of these consist of the few words of Mallicolo, Tanna and New Caledonia, given by Foster in his Observations on Cook's second voyage, and six of 55 words of the Sâman of the Malay peninsula from my own collection, and of those of the Gebe, Waigyu, New Guinea, New Ireland and Vanikoro, the scene of the wreck of La Perouse, from that of M. Gaimard.

An examination of these comparative vocabularies corrects one error of very general acceptance, that the negro languages contain no Malay words, for each of the nine contains Malay words. The proportion of Malay words is considerable in the languages of those tribes which are nearest to the Malays, and therefore most amenable to Malayan influence, and diminishes in proportion to distance or other difficulty of communication. Excluding the numerals, which in most cases are Malayan, the proportion in 100 words of the Sâman is 12; in the Gebe about 8; in the Waigyu above 5; in the Doree Harbour of New Guinea near 4; in the Port Carteret of New Ireland 6; and in the Vanikoro little more than 3. The greater number of Malayan words in all these negro languages consist of nouns or names of physical objects, and none of them can be said to be essential to the grammatical structure. They are, in fact, substantially extrinsic.

A comparison of the native words of the negro languages themselves shows that they agree in a very small number of cases, where the tribes speaking them are in the vicinity of each other. Thus several words are substantially the same in the Waigyu and in the New Guinea. This is, however, the exception, and the rule is a total disagreement. Thus between the language of the negroes of the peninsula of New Guinea and of New Ireland there is not one word alike. There is no evidence therefore to justify the conclusion that the oriental negro, wherever found, is of one and the same race.

On the Geography of Borneo, superadding a Description of the Condition of the Island and of its chief Products, illustrated by Historical References. By W. J. CRAWFURD, *F.R.S.*

On a proposed Canal across the Isthmus of Darien. By Dr. CULLEN.

Notes on Cambodia. By WINDSOR EARL.

A Synopsis of Seventy-two Languages of Abyssinia and the adjacent Countries. By ANTOINE D'ABBADIE, *Paris.*

On an Oreographical Map of Finland. By BARON HARTMANN.

Letter to Mr. Stevens *on his Ascent of Mount Ararat. By* M. KHANIKOFF.

"We were with Colonel Khodzko and four other travelling companions upon the snow-crowned head of this graul, 17,000 English feet high, during the 6th of August. The ascent does not present upon the side which we attempted—that is to say, the Natchwaco side—any great difficulties; above all, with the ample means which we had at our disposal, consisting of cossacks, soldiers, peasants, beasts of burden, tents, provisions, fuel, &c. For myself, I remained twenty-four hours upon the top, having maintained an uninterrupted series of horary observations of the barometer, the thermometer, and the psychrometer, to determine the diurnal changes in the

pressure of the air, the temperature and the humidity at so considerable a height. I descended with Dr. Maretz; but Colonel Khodzko remained from the 7th to the 12th, having to make a series of observations on terrestrial refraction, while the unstable condition of the limpidity of the air during the unfavourable summer of the last year did not permit him to work without great interruptions. What shall I say of the effect of this vast height upon men's constitutions? It does not make itself felt except upon the organs of respiration, which are considerably oppressed by the rarity of the air, of which the mean pressure on the sea-coast corresponds with a height of mercury in the barometer of 760 millimetres, while upon the summit of the Great Ararat it was only 410 millimetres; this causes a certain inconvenience to be felt all over the body, and makes one feel that the circulation of the blood is not carried on as usual. As to the other symptoms indicated by several travellers—such as tightness of the skin, loss of blood by the lips, the gums, the ears, and even the eyes, consequent upon a nervous excitement resembling delirium—nothing of the kind was experienced by any of us. In fact, the inconveniences of our position, which certainly was not very comfortable, arose, not from the height at which we were, but from the cold which prevails at that height (to be experienced everywhere around in winter), and from the snow upon which we lay and in which our little tent was overwhelmed. During the greater part of the time the thermometer was between 9° and 27° Fahrenheit, which with the violent wind which prevails constantly in these regions forms a temperature not very agreeable."

On the Ethnological Position of the Bráhui, and on the Languages of the Paropamisus. By R. G. Latham, *M.D., F.R.S.*

Both these papers were thrown into one, as the question bore upon the ethnology of India. The Brahúi are a peculiar people, with a peculiar language, in Biluchistan, Mekran, and part of Scinde. It had been suggested by Lassen that their tongue had affinities with the southern (Tamulian) tongues of India. This, by new facts, is placed beyond doubt. If so, the displacement by which they are now isolated is remarkable. Reasons were given for considering the Brahúi as an old and aboriginal population of the parts they now occupy rather than recent settlers.

The Paropamisan languages are those of Wokhan and Shugnan, on the head-waters of the Oxus; those of the Dardos and Dhungers on the Indus; those of the Siaposh and Chitrali on the Konur; and those of the Pashai and Lugmani, on or near the Cabul river. To these may be added the Baraki, the Dir and the Tirhai, whose locality was once as far south as the middle of Afghanistan. The great displacements involved in the present confined limits of these populations were enlarged on. Their language was transitional to the monosyllabic tongues and Persian.

On the Volcanic Group of Milo. By Lieut. Leicester, *R.N.*

On the Systematic Classification of Water-Sheds and Water-Basins. By the Rev. C. J. Nicolay, *F.R.G.S.*

Sir R. I. Murchison brought before the Section some notes of Sir James Brooke, the Rajah of Saràwak, "On the Geography of the Northern Portion of Borneo." He pointed out the present state of our acquaintance with the geography of this great island, as derived from the researches of British travellers and surveyors, and as published in the recent map compiled by M. Petermann. He described the communication of the Rajah as important, in making known the ascent, by Mr. Low, of the lofty mountain of Kira Balav (near 14,000 feet above the sea), situated in the north-eastern district, and the intention of Mr. St. John to proceed up the Barram river between Saràwak and Labuan, and to visit the populous country of the Kayans and perhaps that of the Kuineàh—a people unknown to our geography, but numerous and hospitable, and speaking a language distinct from the Kayans or Dyaks.

The Rajah adds, "Some letters from the Kyan chiefs of Barram have lately been printed by order of the House of Commons, and will point out where the real danger to the progress of geographical research is to be apprehended."

On the Ethnology and Archæology of the Norse and Saxons, in reference to Britain. By W. D. SAULL, *F.G.S., Ethn. Soc.*

Ethnological Researches in Santo Domingo. By Sir R. SCHOMBURGK*.

The following are extracts from the letter of the 15th of March 1851, addressed by Sir R. Schomburgk to Prince Albert.—"It is a melancholy fact, that of the millions of natives who at the discovery peopled the island of Santo Domingo, not a single pure descendant now exists; but a careful observer of the mixed races that in a great measure form the population of the Dominican republic will occasionally trace among them the characteristic features of the aborigines. Some stocks of the human race retain their characteristics much more tenaciously than others; the peculiarities of one being lost in a few generations, and those of another being transmitted through several. I have never seen that tenacity more displayed than among the mixed race who to this day are called 'Indios' in Santo Domingo, and in whom the peculiarities of the pure Indian have preserved themselves for more than two centuries. This observation refers chiefly to the female sex of the so-called 'Indios.' Their symmetrical forms, the pure olive complexion and soft skin, their large black eyes, and the most luxuriant hair of an ebony colour, attest at once their descent from the Indian stock. We are told by the historians that the last remnant of the Indians, amounting to from three to four hundred, retired under Enrique, the last of the Caciques of St. Domingo, to Boya, a village about thirty miles to the N.N.E. of the city. Enrique had been converted to the Christian religion, and the Emperor Charles the Fifth ensured to this remnant of the aborigines civil rights and conferred upon him the title of Don. This miserable fragment of a once powerful nation soon vanished from the earth, borne down by their misfortunes and the diseases introduced by the Spaniards. The extirpation of the pure Indian race prevented me from making comparative inquiries between the still existing tribes of Guiana and those that once inhabited St. Domingo. My researches were therefore restricted to what history and the few and poor monuments have transmitted to us of their customs and manners. Their language lives only in the names of places, rivers, trees, and fruits, but all combine in declaring that the people who bestowed these names were identical with the Carib and Arawaak tribes of Guiana.

"An excursion to the calcareous caverns of Pommier, about ten leagues to the west of the city of Santo Domingo, afforded me the examination of some picture-writings executed by the Indians after the arrival of the Spaniards. These remarkable caves, which are already in themselves of high interest, are situated within the district over which, at the landing of the Spaniards, the fair Indian Catalina reigned as Cacique. Oviedo relates that she knew how to captivate the Arragonin, Miguel Diaz. In consequence of a brawl with one of his companions, whom he supposed that he had mortally wounded, Diaz fled from Isabella and found an asylum at Catalina's village. Fearful of losing her lover, who after a few months seemed to long to return to his companions and his accustomed occupations, Catalina employed the most powerful means she could have resorted to in order to induce the Spaniards to settle within her own territory, concluding naturally that this would ensure the continued presence of Diaz. She related, therefore, that the adjacent mountains possessed rich mines, and drew his attention to the superior fertility of the soil, which so much surpassed that upon which Columbus had founded Isabella; moreover that the river Ozama afforded at its entrance a secure and fine harbour. Diaz returned with this information to Isabella, where he found to his joy the man recovered from his wounds whom he thought he had killed, and the report of the rich mines produced him an easy pardon. The Adelantado, Bartholomew, who governed in the absence of his brother, visited the district himself, and erected, in 1496, a fortified tower in

* Communicated by H.R.H. Prince Albert.

the neighbourhood of the mines, which he called San Cristobal; but the workmen who built it, finding the precious metal even in the stones they used for its construction, named it the 'Golden Tower.' The mines were soon exhausted, and the country assumed again the aspect of exuberant nature. When, therefore, the covetousness and cupidity of the Spaniards sacrificed the lives of millions of Indians to their idol, Gold, the caverns which previously had only been used for their worship became now a retreat from the Spanish crossbows, and the frightful bloodhound sent in pursuit of the poor Indian. * * I was greatly interested in a number of symbolic pictures which the Indians had traced with charcoal on the white and smooth walls of one of the smaller caves, which bears at present the name of the 'Painted Chamber.' Peter Martyr of Angleria, the contemporary of Columbus, and one of the earliest historians of his discoveries, relates, in his first decade of the 'Ocean,' that the aborigines of Santo Domingo held caves in great veneration, for out of them, they say, came the sun and moon to give light to the world,—and mankind likewise issued from two caves of unequal height according to the size of their statures. In the general uncertainty which prevails with regard to these monuments of by-gone races, it was particularly gratifying to find these sculptures, which afforded a clue to the period when they were executed. * * Near the entrance of a second cave, close to the former, I observed some carvings in the rock. The character of these figures, and their being cut in the hard substance of stone, prove an origin of a more remote date than those in the other cave. * * Baron Humboldt observes, when alluding to the carvings he met on the banks of the Orinoco, that 'it must not be forgotten that nations of very different descent' when in a similar uncivilized state, having the same disposition to simplify and generalize outlines, and being impelled by inherent mental dispositions to form rhythmical repetitions and series, may be led to produce similar signs and symbols.' Baron Humboldt had only opportunity to view the carved figures on the banks of the Orinoco, but the examination of a great number of these symbols shows to me that there is a great difference in their character and execution; nor is it my opinion that the idols worked in stone and the carvings on the rocks were executed by the races that inhabited South America and the West Indies at the time of their discovery. They belong to a remoter period, and prove much more skill and patience than the simple figures painted with charcoal on the walls of the cave near Pommier. The figures carved of stone and worked without iron tools, denote, if not civilization, a quick conception, and an inexhaustible patience to give to these hard substances the desired forms. * * With respect to the age or epoch when the figures sculptured of stone were executed there is no tradition. It is remarkable that they are only found where we have sure evidence that the Caribs inhabited or visited the place. I have no reason to believe that they were made by the Caribs, which opinion I am the more inclined to adopt on comparing them with the tools and utensils executed by the still existing tribes I met in Guiana. There are, however, various proofs that the Caribs inhabited Santo Domingo; among others, I found at the eastern point of the island, called Junta Engaño, numerous heaps of Conch shells (*Strombus gigas*). These shells have invariably a hole near the spire, which has been made for the purpose of detaching the animal from the shell, and to extract it with ease. I met a large number of similar piles at the island of Anegada, which the historians of the Antilles ascribe to the Caribs, who, on their descent from the Lucuyas to wage war upon the natives of Puerto Rico, touched first at Anegada in order to provision themselves with conchs for their expedition. A far more interesting discovery than these heaps of conch shells, during my travels in Santo Domingo, is, however, a granitic ring in the neighbourhood of San Juan de Maguana, which seems to have entirely escaped the attention of previous historians and travellers. Maguana formed one of the five kingdoms into which Santo Domingo, on the arrival of the Spaniards, was divided. It was governed by the Carib Cacique Caonabo (which name signifies *rain*), the most fierce and powerful of the chieftains, and the irreconcileable enemy of the Europeans. His favourite wife was the unfortunate Anacaona, famed in the island for her beauty, her wisdom, and, as recorded by all the early historians, for her kindness towards the white men. Nevertheless, Ovando, when governor of Santo Domingo, accused her of conspiracy, and carried her in chains to the city and ignominiously hanged her in the presence of the people whom she had so long and so signally befriended. The granitic ring is now

known in the neighbourhood under the name of 'el Cercado de los Indios,' and lies on a savannah surrounded with groves of wood, and bounded by the river Maguana. The circle consists mostly of granitic rocks, which prove by their smoothness that they have been collected on the banks of a river, probably at the Maguana, although its distance is considerable. The rocks are mostly each from thirty to fifty pounds in weight, and have been placed closely together, giving the ring the appearance of a paved road, 21 feet in breadth, and, as far as the trees and bushes which had grown up from between the rocks permitted one to ascertain, 2270 feet in circumference. A large granitic rock, 5 feet 7 inches in length, ending in obtuse points, lies nearly in the middle of the circle partly imbedded in the ground. I do not think that its present situation is the one it originally occupied; the rock stood probably in the centre. It has been smoothed and fashioned by human hands; and although the surface has suffered from atmospheric influence, there is evidence that it was to represent a human figure: the cavities of the eyes and mouth are still visible. This rock has in every respect the appearance of the figure represented by Père Charlevoix in his 'Histoire de l'Ile Espagnole ou de Saint-Domingue,' which he designates as a 'Figure trouvée dans une sépulture Indienne.' A pathway of the same breadth as the ring extends from it first due west, and turns afterwards at a right angle to the north, ending at a small brook. The pathway is almost for its whole extent overgrown with thick forest; I could not, therefore, ascertain the exact length. No doubt can exist that this circle surrounded the Indian idol, and that within it thousands of the natives adored the deity in the unshapen form of the granite rock. But another question remains to be solved, namely, Were the inhabitants whom the Spaniards met in the island the constructors of this ring? Were they the adorers of this deity? I think not. * * Among the antiquities recently discovered near San Diego, within a day's march of the Pacific Ocean, at the head of the Gulf of California, were likewise granitic rings or circular walls round venerable trees, columns, and blocks of hieroglyphics. If my opinion could possess any value, I should pronounce the granitic ring near San Juan, the figures which I have seen cut into rocks in the interior of Guiana, and the sculptured figures, to belong to a race far superior in intellect to the one Columbus met in Hispaniola, who came from the northern parts of Mexico, adjacent to the ancient country or district of Huastecas, and that this race was conquered and extirpated by the nations that inhabited the countries when the Europeans landed. * *

"I venture to hope that the account of my discoveries of a few monuments that have descended to us of a by-gone race, may not be entirely unacceptable. I intend to commence my journey to the northern provinces, for the execution of which I have already received the permission of Lord Palmerston; in a few days I promise myself a rich harvest among the ruins of the first settlements and fortifications which the Europeans erected in the New World."

On the Geography of Kumáon and Garhwál in the Himálaya Mountains. By Capt. R. Strachey, *Bengal Engineers.*

Capt. Strachey began by giving a sketch of the general configuration of the surface of Central Asia, in which he pointed out that the elevated region known as Tibet, formed the summit of a great protuberance above the general level of the earth's surface, of which the two mountain chains, known by the name of the Himalaya and Kouenlhen, were nothing more than the south and north faces, these ranges having no definite special existence apart from the general mass. He then proceeded to give a more detailed account of the main physical features of the British provinces of *Kumáon* and *Garhwál* in the Himalaya, and of the part of Tibet contiguous to our frontier, to which his own observations had been restricted. The plains of northern India extend along the entire southern edge of the Himalaya over about 500,000 square miles, nowhere exceeding in elevation 1200 feet above the sea. From these rise the mountains suddenly and in a well-defined line. The exterior range, called the Siwaliks by Dr. Falconer and Col. Cautley, is of no great elevation, hardly exceeding 3000 feet. The characteristic tracts of swamp and dry forest that occur along its southern face, known as *Tarai* and *Bhábar*, and the longitudinal valleys

called *Dún* along its northern slope, were described. Immediately above these rise the first ranges of the great mountain region that extends to the north over a breadth of upwards of 200 miles. The loftiest peaks, some of which exceed 28,000 feet in height, are usually found along a line 80 or 90 miles from the southern edge of the chain, which in Kumáon neither is coincident with the water-shed, nor forms a continuous ridge, but is broken up into groups separated by deep gorges, and connected by transverse spurs with the water-shed range that runs 20 or 30 miles further to the north. On crossing this water-shed, which forms the boundary between Tibet and our provinces, the traveller finds himself, not without astonishment, on a plane 150 miles in length, and 36 or 40 in breadth, the elevation of which varies from 16,000 feet along its southern edge, to 14,500 feet in its more central parts, where it is cut through by the river Sutlej. It is everywhere intersected by stupendous ravines, that of the Sutlej being nearly 3000 feet deep, which are furrowed out of the alluvial matter of which the plain is composed. The mountains that bound this plain to the north hardly enter the region of perpetual snow, the famous peak of *Kailás*, which is nearly 22,000 feet in altitude, being the highest point.

Capt. Strachey then gave a brief account of his first journey into this country, in which, in company with Mr. J. E. Winterbottom, he reached the lakes of Rákas, *Tál* and *Mánasarowar*, which are found towards the eastern extremity of the plain at an elevation of 15,200 feet.

A general view of the geology of these regions followed, from which it appeared that from the Siwalik range, which was before known to be of tertiary age, the mountains are formed of metamorphic rocks, until we pass the line of greatest elevation. We then again find fossiliferous rocks which form a regular sequence from the lower Silurian to the tertiary formations. Fossils from all of these beds have been collected and brought to this country by Captain Strachey. It is of the tertiary beds that is composed the great plain already described, and in them have been found fossilized remains of elephants and rhinoceros at an elevation of between 14,000 and 15,000 feet above the sea.

From a general consideration of these circumstances, it was inferred that the present wonderful development of the Himalaya and of the elevated regions of Tibet dates no further back than the tertiary period, being in fact one of the most recent changes that the surface of the earth has undergone.

Proceeding from the solid crust of the earth to its aërial covering, an account was next given of the chief meteorological phænomena, among which it will be sufficient to specify two of the most remarkable, namely, the glaciers and perpetual snow. Glaciers were shown to abound in all parts of the mountains covered with perpetual snow, descending as low as 11,500 feet.

The snow-line, the height of which has given rise to much discussion, was stated to descend to about 15,500 feet on the southern face of the Himalaya, while it was pointed out, that as we advance to the north of the great peaks and stand on the mountains bordering the Tibetan plain, the snow-line has receded to 19,000 or 20,000 feet. This phænomenon was shown to depend chiefly on the fact, that the quantity of snow that falls to the north of the great Himalayan peaks, is far less than that which falls on their southern slopes.

Capt. Strachey then passed to the description of the vegetation of these mountains. Its character was shown to be truly tropical up to elevations of about 4000 feet, though even from 3000 feet some of the forms of temperate climates begin to appear. The remarkable admixture of these temperate forms with those of the torrid zone, that is met with in the valleys of the larger rivers that penetrate at a very low level far into the interior of the mountains, was also noticed. Above 4000 feet, oaks, rhododendrons and andromeda, form a very great proportion of the forest up to 7000 feet; although in many places the *Pinus longifolia* clothes the slopes of the hills to the exclusion of everything else, nearly within the same limits of from 3000 to 6000 feet.

As we ascend species of the deciduous trees of colder climates are introduced, and they, with the addition of other pines, prevail in the upper parts of the forest, from 8000 to 11,500 feet, where arboreous vegetation is usually found to terminate rather suddenly. Above this a more open tract succeeds in which the vegetation is for the most part herbaceous, few shrubs ascending so high as 14,000 feet.

As we recede in our progress to the north, behind the higher summits of the range, the country rapidly becomes more arid; and when we reach the plain of Tibet, we find it to be almost a desert, on which few plants rise even to the height of a single foot.

The vegetation, which, though scanty, is still highly interesting from its similarity to that of the arctic regions, may be considered finally to cease at about 17,000 or 18,000 feet.

After referring to the agriculture of this tract, in which the profitable cultivation of the cereal grains was shown to be carried up to about 14,000 feet, Capt. Strachey concluded by an account of some of the zoological characteristics of the Tibetan plateau. He mentioned more particularly the *Kyang* or Wild Ass, the *Yak*, the wild and domestic Sheep and Goat, the Ounce, and other animals, specimens of which he brought with him from that country, and which have lately been set up in the East India Company's Museum.

On the Inhabitants of Kumáon and Garhwál.
By John Strachey, *Bengal Engineers.*

After alluding to the difficulty of arriving at satisfactory conclusions regarding the ethnological relations of the tribes inhabiting the Himálaya, in consequence of that range of mountains lying on the boundary-line between two or more races, Mr. Strachey proceeded to give some account of the people called Khasiya, which comprises the greater part of the inhabitants of Kumáon and Garhwál. A tribe of the same name is spread extensively over the greater part of the Nepalese territories, and it has been assumed, from this circumstance and other facts observed in the eastern parts of the Himalaya, that the Khasiyas generally are a people of mixed Tibetan and Indian race. Although this may perhaps be true of the Khasiyas of Eastern Nepál, Mr. Strachey considered that it was by no means proved to be the case as to those of Kumáon, and he doubted whether the signs of any non-Indian stock were more definite in the people of Kumáon than in those of the plains of Northern Hindustan. In form and feature, in language, religion, and customs, the Khasiyas of Kumáon appear to be Hindu, and all their sentiments and prejudices are so strongly imbued with the peculiar spirit of that faith, that although their social habits and religion are often repugnant to Hindu orthodoxy, it is difficult for one who knows them to consider them as anything but Hindu. The custom of polyandry does not prevail in Kumáon and Garhwál. Mr. Strachey pointed out why he considered that the existence of this custom did not necessarily prove descent from a Tibetan stock, and how it might grow up in a purely Hindu community, as a consequence of the general social state. Historical evidence helps to confirm the opinion that the Khasiyas of Kumáon are of Hindu origin. It is proved by ancient inscriptions found in Garhwál, that, say fifteen hundred years ago, the Hindu religion was in full force in these provinces, and that in the country itself the people were then known by the name Khasa. In Manu, the Máhábhárata, and in several of the Puránas, we read of a race of Kshatriyas called Khasa, dwellers in mountains, who have become degraded by the neglect of religious rites, and it is curious that the Khasiyas of Kumáon at the present day give an almost exactly similar account of themselves. After speaking of some of the social and economical peculiarities of the Khasiyas, Mr. Strachey proceeded to give an account of the Bhótiyas, the most important of the tribes of Tibetan origin found in Kumáon and Garhwál, inhabiting the country near the Tibetan frontier, among the highest parts of the Himalayan chain. Their villages are situated at elevations varying from 7000 to 12,000 feet above the sea; but the Bhótiyas derive their chief means of subsistence, not from agriculture, but from the carrying trade between Tibet and the Cis-Himalayan states, of which they possess a monopoly. An account was given of this trade, and of their general habits, religion, languages, &c. Of their Tibetan origin there can be no doubt. The adjoining province of Tibet was also referred to. The name of this country is *Húndes*, the land of *Huns*; not *Hiundes*, the snow-country, nor *Oondes*, the wool-country, as it has been variously termed. Fron ancient inscriptions found in Garhwál, of which Mr. Strachey intended to give an account hereafter, it is proved that the country in ques-

tion was called *Huna* probably more than 1000 years ago, and there can be no doubt that the race of *Hunas*, often mentioned in the Purânas, must be referred to the same country. This fact seems to help to corroborate the views of the Chevalier Bunsen and of other ethnologists regarding the origin of the Huns in the countries on the northern borders of the Himalaya.

Notice of Travels in Asia Minor. By PIERRE DE TCHIHATCHEFF.

Observations on some Aboriginal Tribes of New Holland. By DR. T. R. HEYWOOD THOMSON, *F.Eth.Soc.*

Notes on the Australians. By MR. TOWNSEND.

On the best Means of realizing a Rapid Intercourse between Europe and Asia. By ASA WHITNEY.

On the Inhabitants of Lower Bengal. By ROBERT YOUNG, *E.M.R.C.S., Surgeon to his Highness the Newab Nazim of Bengal.*

In this paper Mr. Young gives a few particulars of the inhabitants of Lower Bengal, from personal observation, but confines himself to replies to the set of ethnological queries which were circulated by the British Association.

Physical Characters.—The general stature of the men is low; the proportions of the figure are not good, and the weight is light, being on an average 130 lbs. The women are larger in porportion and better made; this may be attributable to the development of the muscular system, in consequence of hard or household work, carrying water, &c., while the men are engaged in agricultural pursuits.

The head is generally large, as is the abdomen; the extremities usually meagre, and the joints small.

The complexion is of a colour hardly describable, and varies considerably from bronze to black, but never assuming the copper hue of the South American Indian. The hair is never woolly, but is of a good black, and generally curly; it is sometimes fine and sometimes coarse and straight, but mostly what we should term "a beautiful head of hair." The colour of the eyes varies; but with the description of hair just given, you generally find eyes black and glossy. When the hair assumes a reddish brown tint, the eye is often gray or hazel, and in such cases the complexion is always lighter. These variations I have particularly observed; and among the natives of the country, these men of lighter complexion are generally considered as of treacherous character; but this remark I make not from my own observation. The shape of the eye is always round rather than long, but it varies as in all other nations. I have never detected any peculiarity of odour whatever, and should decidedly say there is *none*.

The head is, as I have said, large, and elongated from the front to the back; the ear is set remarkably far back in the temporal region, and the powers of perception exceedingly low. I am unable to furnish sketches, as suggested by your Committee, having quitted India at very short notice, and the men accompanying me not belonging to the part of the country described as Lower Bengal, to which my observation has been principally directed. Idiocy is very common among the Hindoos. As a people they possess a wonderful power of maintaining an imperturbable expression of countenance under the most adverse circumstances, and of concealing their emotions, whether of pleasure or pain. This arises by no means from apathy, but from innate deceit in the character, and is often made available for personal advantage.

The bones of the skull are thin and light, and the frontal bone is occasionally found with a suture in the middle: this is not common. But in giving a reply to this

question, I must observe that the facilities for the study of anatomy are, *out* of Calcutta, exceedingly few, from the fact that exhumation is absolutely necessary in the case of Mussulmen; and the body of a Hindoo is almost unattainable, because that of the rich man is almost invariably subjected to cremation, while the Ganges is the final home for the bodies of the poor. They have *no* practices for modifying their form or appearance in any way, and never trouble themselves with a superfluity of clothing.

The pelvis in the female is largely developed, and hence the facility and comparative absence of pain in parturition. The foot, generally speaking, is well-formed; and in cases where hard labour has not affected the frame, the foot, hand and arm may be taken as models for the sculptor.

There is in the district of Lower Bengal only one race of men, no intermixture; but there is sometimes in the same family a wonderful difference in the complexion. I have in my own service two brothers, natives of Orissa, a district south of Calcutta, one the eldest, the other the youngest of the family. The skin of the first is remarkably dark, almost black, while that of his younger brother is particularly fair, and I have remarked this in other instances. It is worthy of observation that this occurs in a family where no polygamy has ever occurred. Among the Hindoos it is not allowed for separate castes to intermarry, but this law does not extend to the whole family of the Mahomedans, of whom there are five distinct sects, namely the Pâtan, the Mogul, the Syud, the Shaik, and the Sheah, intermarriage being permitted among some of these, but not all.

The inhabitants of Lower Bengal are anything but a long-lived people; and I am inclined to think this is the case throughout Hindostan; the causes may be more than I can enumerate, for they are many. Foremost, that of early marriage, much more physical weakness naturally than the men north of *Behar*, who are stronger and more athletic. I mention *Behar* for two reasons: first, it is the extremity of the Bengal Presidency; and secondly, I have myself observed the fact and been struck by it. Poverty of food probably has some weight, but the consumption of opium and hemp in various forms doubtless tends to swell the list of unfavourable influences.

Language.—Among the working classes, the common Bengalee language, which is nearly pure, is spoken; all their accounts are kept in Bengalee; their native newspapers, of which there are several published in Calcutta, are in the same. Among the middle classes we find Hindostanee in use, occasionally interspersed with words of Bengalee. But at court, and in the highest ranks of the natives, Hindostanee in its purity, and also Persian, are commonly found. The Bengalee does not rule anywhere beyond the three districts I have mentioned, *Bengal, Behar*, and *Orissa*. The people of the last-mentioned district, or Ooriahs, have, in addition, a language of their own; but little Bengalee is spoken in Behar.

The literary knowledge of the Mussulman is almost confined to his Koran; and, to his Shastres, that of the Hindoo. They have their native songs, set to very simple airs, and appointed for different times of the day and night; those for the morning, the day, and a part of the night being of a varied and cheerful description, while those after midnight and towards the break of day are extremely plaintive and agreeable; the subjects of these latter may be divided into two,—the love ditties of the country, and the morning invocations to the various deities. These latter, to the ear of a lover of music, are exceedingly pleasing, being sung in a delicate falsetto voice.

Individual and Family Life.—There is a general rejoicing at the birth of a son; but from the low esteem in which women are held throughout the whole of India, the birth of a daughter as a first-born child is considered as an affliction in the family. Should however a daughter be the second child, the distress of the event is considerably mollified.

I have never known infanticide in the case of a son, but the above reasons induce a degree of want of affection for female children, who, happily however, are not so extensively destroyed as in times past.

Less pains in dressing or clothing children cannot be taken than by the Hindoo: there is no artificial plan of modifying the form in any way, either amongst Hindoos or Mussulmen.

Education can nowhere be at a lower ebb than it is at present in Bengal. The children are absolutely taught nothing! Predestinarians in the extreme, they are exceedingly indifferent to life, and professionally speaking, I may say they are adverse to anything like a surgical operation, *fate* being all in *all*, to them. The field for discussion on these points is wide, and I might be digressing from the objects of your Committee, were I to expatiate on the present mode of education pursued by philanthropists who have lately taken up the subject in India. To the education of our own sex there never has been any obstacle, but against that of the female, have been pitted the custom of the country, the superstition of the parties themselves, and the extraordinary ascendency maintained by their pundits or priests over every class of society. I would give the palm to the Mussulmen in point of thirst for knowledge and freedom from moral tyranny; they rank far before the Hindoos; they are freer from superstition and crafty priesthood; and from being more of one family among themselves, I believe their creed to be of a better stamp than that of the Hindoo, whose name is Legion as to variety of caste.

Puberty takes place at a very early age. I have *known* a mother as young as eleven; and I have heard of such even at an earlier age. Families, generally speaking, are not large; I think three is the outside average: a twin birth is not common.

Children are taken very little care of; bad nursing, bad nourishment, and hence their stunted and frequently squalid appearance.

As to the age to which children are borne, I consider thirty above the mark; being given in marriage as early as four or five years of age, and being passed over to the husband at the first attainment of puberty. I am not aware of any ceremonies being connected with particular periods of the life of a child, excepting the circumcision of the Mahomedan, and the investment of the Brahminical thread of the Hindoo. On both these occasions there is a religious ceremony, simply invoking blessings on the respective heads of the parties.

Chastity is scarcely known; among the higher classes it is, from their position, more observed, it being difficult for the women of rank to leave the zenana; but where the sanctity of the harem is not observed, married life is only a name. I am not aware of any superstitions on this subject; rejoicing and feasting are the accompaniments of a marriage, a procession always taking place on the occasion; the priests being the parties who simply let the parents understand that the marriage has taken place, and there it ends. Divorce is not known, and for this reason polygamy is frequent; and although there is one wife whose station is considered superior to any other, the offspring of others is equally legitimate. Widows, from not being allowed to marry a second time, whatever age they may be, almost invariably go astray, and are consequently looked down upon as outcasts.

The sick are generally treated by their own native medical men, three-fourths of the treatment consisting of faith, superstition and charms, and the remaining fourth in the administration of some vegetable medicine adapted to cure the disease.

Survey of the Southern Part of the Middle Island of New Zealand. *By* Capt. J. L. Stokes, *R.N., F.R.G.S.*

Having been employed in 1844 by the New Zealand Company to explore the eastern and southern coasts of the middle island of New Zealand, in order to select a suitable site for the then projected settlement of New Edinburgh, I had occasion to examine carefully the district described. I can fully confirm the accuracy of these observations in respect to the vast extent of available surface which exists south of Tuturau and the Mataura river to the shore of Leveause Straits, between the Eurete or New River and the Aparima westward, as also to the east of the Eurete. I cannot however concur in recommending it as a district eligible for a settlement; instead of its affording good pasture for grazing, or fertile soil for husbandry, in my judgement the surface is rather rude, and the vegetation chiefly large detached bunches of a very coarse sharp-edged junk. Where the banks of the Aparima and Eurete are wooded, I found chiefly the Totara and the Manuka growing luxuriantly, but in deep sand, whilst those portions of the gently undulated uplands, which are wooded, afford almost exclusively varieties of the birch, which abounds and attains great

dimensions even on the poorest land. The earth presents a surface of a whitish hue when dry, without mould or humus, being a deep and gritty clay (as I found by frequently digging), which I am convinced would not bear any adequate crop without being first well manured. Between the east and west branches of the river Eurete the land is low and sandy. Eastward to the coast is a vast bed of fine quartz gravel covered with heather and luxuriant mosses; and in some places occurs peat of pretty good quality and considerable depth. There is good timber at the western extremity of the Bluff harbour, and between it and the river Eurete some extent of bush land, in and around which a herd of cattle find sufficient pasture, but feeding chiefly on the milk-thistle, &c. There is a small community of Europeans at the Bluff and at the Aparima, who have intermarried with the natives, and who, pursuing whaling, sealing and husbandry, and in a few instances stock-keeping, have attained to very comfortable circumstances. Some were in the practice of growing wheat, but they informed me that the climate was unfavourable, rains being frequent and copious, and the gales of wind boisterous. While my vessel lay at anchor in the Eurete in the month of May, we had to encounter, in the surveys executed and on our several exploratory journeys, very inclement weather. Considering, then, the climate, the soil, and the natural growth, I am convinced that there is no very eligible site for a future settlement south of the Mataura river and *Tu-tu-rau*, a favourite residence of the natives formerly, when they were more numerous, because it afforded shelter from the southern climate, good fishing and fertile land. From Tu-tu-rau north to Otokau, there is an unbroken tract of fertile and well-watered land, affording abundant pasture, and much of it of excellent quality for tillage. It abounds with supplies of coal, wood, timber, brick-earth and stone, conveniently dispersed through the district and very accessible by the facilities of inland navigation, which its rivers and lakes afford. Again, for fifty miles north of Otokau there is a district presenting almost equal capabilities for large productiveness. Further north, along the ninety miles beach, extending about twenty-eight miles above Banks Peninsula, there is a vast plain, for the most part either too arid and stony, or too wet and swampy to be eligible for occupation. There is but a very limited quantity of fertile land good enough for tillage within a distance of twenty miles of either of the harbours of Banks Peninsula. The surface of plains in New Zealand usually presents a succession of terraces in lines parallel with the course of the rivers, rising in steps of from six to fourteen feet in elevation; much of the surface is desolated by closely-imbedded boulder and shingle, and usually where these occur in the greatest breadth, and where there is a dead level, the surface is the most stony. On the hill lands of Banks Peninsula there is good pasture, but it is not so on the plain. My reasons for rejecting it as ineligible for the site of a settlement, as well as my report of the entire journey of exploration which I made in 1844, are alluded to, but not adduced in the Seventeenth Report of the Directors of the New Zealand Company, and the substance of the same will be presented to the public under the head of Topography of the Middle Islands of New Zealand, in the valuable work on British Colonies, written by R. M. Martin, Esq., which is now published in monthly parts by Messrs. Tallis and Co.

Ascent of Orizaba in Mexico. By E. Thornton.

STATISTICS.

On the Statistics of New Zealand. By H. S. Chapman.

The Secretary read a communication by Mr. Cocks "*On the Mortality in different Sections of the Metropolis in* 1849."

On the Mortality in different Sections of the Metropolis in 1849. *By* T. Corle.

On the Vital Statistics of the Armies in the East India Company's Service. By Dr. Cuthbert Finch.

Statistics of the Attendance in Schools for Children of the Poorer Classes. By Joseph Fletcher.

This was an elaborate abstract of the attendance, ages, and instruction of the children in about 160 schools, two-thirds British and one-third Wesleyan, inspected with reference to the apprenticeship of pupil-teachers, in the course of the year 1850. Their experience is that of the best class of town schools for the poorer classes, those which are merely infant schools being excluded from the abstract, and the attendance in the remainder derived chiefly from the families of skilled artizans and small shopkeepers. The number entered upon the books within the 12 months preceding the date of inspection, was, in 139 schools, 13,728, and the number erased from them 10,989; showing a decided tendency to increase, with the increasing power of instruction supplied by the pupil-teachers, but a lamentable amount of fluctuation; the new admissions amounting to 84 per cent., and the withdrawals to 64 per cent. of the number in ordinary attendance.

Fluctuations in the School Population.

	Boys.	Girls.	Mixed.	All.
Average numbers in each class of schools :—				
Admitted within the last 12 months...	113	85	92	99
Left within the last 12 months	96	68	65	79
In ordinary attendance	134	105	108	118
Present at Examination	129	101	100	112
Per-centages on average of ordinary attendances :—				
Admitted within the last 12 months...	84·3	81·0	85·2	84·0
Left within the last 12 months	71·6	64·8	60·2	67·0
Present at Examination	96·3	96·2	92·6	95·0

The excessive fluctuation indicated by this table affects chiefly the lower half of each school, where the poorer quality of the instruction which has heretofore prevailed, the indifference of the parents, and the want of better check on the part of the teachers, have often perpetuated a very inferior kind of management.

Abstract of the Ages of the Children in 142 *Schools, exclusive of Infant Schools, and containing* 20,399 *Children.*

	Boys.	Girls.	Mixed.	Total.
Average number of an age—				
Not exceeding 7	49	41	42	45
7 " 8	24	18	16	20
8 " 9	25	16	17	20
9 " 10	23	16	15	18
10 " 11	18	12	14	15
11 " 12	12	10	12	11
12 " 13	8	8	8	8
13 " 14 and upwards	6	8	9	8
Total	165	129	133	145
Per-centage on total number—				
Not exceeding 7	30·1	31·9	32·0	31·1
7 " 8	15·0	13·6	12·4	13·9
8 " 9	15·1	12·4	13·1	13·9
9 " 10	13·9	12·4	11·9	12·9
10 " 11	10·9	10·0	10·2	10·4
11 " 12	7·2	8·3	8·7	7·9
12 " 13	4·5	6·0	5·2	5·1
13 " 14	3·3	5·4	6·5	4·8

Thus one-third of the children in the schools which are not reckoned as infant schools, are of the infantile ages not exceeding 7, while only 4·8 per cent. are upwards of 13, and only 9·9 per cent., including these, upwards of 12 years of age. This latter therefore may be considered to be the age at which the children of artizans generally cease to attend any day school, a large proportion of those above that age being the children of parents of rather superior means. The relative excess of boys at the younger and girls at the more advanced ages, is referable to the greater usefulness of the latter at home; and the fact that a larger proportion of a somewhat higher class are generally to be found protracting their stay in these even than in the boys' schools. The children of the unskilled labourers being seldom allowed to attend school to ages ranging so late within two years as those returned in the preceding table, it is obvious that there is no opportunity for the "over-education" of the people by the day schools, let them be made ever so vigorous; while the following table of the school occupations of the 20,399 children under present observation—enjoying the best advantages of any in their station of life—will further evince how fallacious is any such apprehension.

Abstract of the per-centage proportions of the preceding 20,399 *Children returned as receiving instruction in each of the following subjects in* 161 *Schools.*

		Boys.	Girls.	Mixed.	All.
Letters and Monosyllables		22·1	26·2	25·9	24·3
Easy Narratives		30·9	31·8	26·4	29·9
Holy Scripture		58·2	52·8	47·3	53·7
Books of general information		50·5	36·0	43·5	44·7
Writing on Slates.	From Copies	41·8	50·5	34·6	41·9
	From Notation or Memory	39·7	27·6	30·7	33·9
	Abstracts or Composition	15·6	4·5	10·3	11·2
Writing on Copies.	From Copies	65·1	47·4	58·5	58·5
	Abstracts or Composition	10·1	6·3	7·9	8·4
Arithmetic.	Numeration or Notation	21·3	20·2	16·5	19·7
	Addition, Subtraction and Multiplication	23·7	26·1	24·6	24·6
	Division	19·1	14·6	17·1	17·3
	Compound Rules and Reduction	20·2	15·8	14·6	17·5
	Proportion or Practice	11·7	3·4	8·5	8·6
	Fractions and Decimals	8·1	·1	5·8	5·3
Grammar		50·5	36·1	36·4	42·7
Geography		59 0	43·5	51·4	52·7
History		30·0	18·9	19·3	24·0
Vocal Music from Notes		17·9	7·2	7·4	12·1
Linear Drawing		16·8	......	5·0	9·0
Geometry		3·7	......	1·1	1·9
Mensuration		4·9	......	3·8	3·2
Algebra		2·4	......	1·2	1·4
Sewing or Knitting		......	76·0		

Thus in this highest class of schools for the children of the poorer classes, there is only about 8½ per cent. whose occupations in writing abstracts or compositions, and in learning the rules of proportion and practice, indicate their advancement beyond the merest elements of reading, writing and "counting." While only 5·3 per cent. work in fractions, 1·9 per cent. are acquiring the poorest elements of geometry, and 1·4 per cent. of algebra. A large proportion of these more advanced scholars are of the middle classes, to whose children even this amount of instruction has heretofore been almost entirely restricted. The greater part of that which is designated grammar, geography and history, in the accompanying table, is of a character to invalidate the figures which describe the proportions receiving instruction in these branches.

M. Guerry exhibited eighteen coloured Maps illustrating some important conclusions respecting *the Criminal Statistics of England for* 16 *years, ending* 1850.

He had brought over from France a similar series of maps to illustrate the same points in the criminal statistics of France; but as they had been placed in the Great

Exhibition, he had been unable to get them out for the purpose of producing them to the Section.

The leading point which he had established for France was, that the common opinion respecting the intimate connection between mere instruction and the absence of crime in particular districts, when compared, was mistaken. The facts on which the calculations in the English maps were founded were taken from the tables drawn up by Mr. Redgrave of the Home Office, for all the time that had been collected. Each map was constructed to show the prevalence in each county of England of a particular crime or class of crime, such as murder, manslaughter, arson, larceny by servants, offences against the game laws, bigamy, &c. As to bigamy, there was a most remarkable difference between England and France, that crime appearing to be much more prevalent in England. He accounted for this circumstance by the difference in the forms of marriage required by law, which afforded much greater facilities for tracing personal identity in France than in England.

The English maps were constructed to the degrees of criminality as measured by the average number of the accused for the whole period of sixteen years, as compared with the average population, as ascertained by the three censuses of 1821, 1831 and 1841.

Besides the maps, he showed a series of tables exhibiting, by curved lines for each county, the degrees of positive and negative criminality corresponding with the coloured maps.

As to the French maps, there were one or two points which he was anxious to notice. The geographical distribution of instruction among all the young men of 20 years of age in France was easily observed, in consequence of the mode used for selecting the soldiers for the French armies. He had analysed the returns made of these young men by the prefects of France to the Minister of War for 22 years ending 1849, and the result as to parallelism of distribntion of mere instruction and absence of crime which he had stated 17 years ago in his work on the 'Moral Statistics of France,' was fully borne out.

This second analysis had established another interesting result, that the progress in the amount of instruction in each department of France, instead of being in the districts where most wanted, had on the contrary been, with singular regularity, in the districts where the greatest instruction had previously prevailed.

On the Prospects of the Beet-Sugar Manufacture in the United Kingdom. By Professor W. Neilson Hancock, *LL.D.*

Public attention had been directed to this manufacture by the efforts to establish a public company in London for its introduction into Ireland. The Professor had learned that at Maldon the manufacture had been attempted by a private company, but this attempt led to failure in a short time. A manufactory had very recently been established at Chelmsford, and contracts had been entered into with the farmers in that neighbourhood. The prospects of the manufacture depended on the answers to three questions:—1st. What was the price of beet-root likely to be for a series of years? 2nd. What was the price of refined beet-sugar likely to be after 1854? and 3rd, Would it be profitable to carry on the manufacture at these probable prices of the raw produce and manufactured article?

As to the price of beet-root, its price varied in France from an average of 13*s.* 11*d.* per ton in the north-east of France, to 18*s.* 5*d.* per ton in the north-west of France. The average for the whole of France was 15*s.* 1½*d.* per ton. In Ireland the price stated to be contracted for by the sugar beet company was 15*s.* 6*d.* per ton, and the price at Essex was from 18*s.* to 20*s.* per ton. Thus it appeared that the present price in Ireland was higher than the average of France, and the present price in England was higher than the average of the highest-priced districts of France. What the future price in Ireland and England was likely to be, was a difficult question, and had not been as yet fully investigated.

As to the second question, the price of refined beet-sugar after 1854, it was necessary to take the year 1854, because at present there was a differential duty in favour of home-grown beet-sugar, which would diminish each year, and cease after July 1854. After that time the short price of refined beet-sugar would most

probably not exceed 27*s.* to 28*s.* per cwt., and the long price would most probably not exceed 40*s.* 4*d.* to 41*s.* 4*d.* per cwt. Indeed a fall below those prices might be anticipated from three causes:—1st. From the diminished cost of production of refined cane-sugar, consequent on the increased consumption produced by the fall in its market price from 49*s.* 4*d.* to 42*s.* 4*d.* per cwt. on the equalization of the duties. 2nd. From the removal of the absurd restrictions now imposed on cane-sugar refiners. And 3rd, from the competition between cane-sugar and beet-sugar, if the latter were manufactured to any extent.

As to the third question, Would it be profitable to manufacture from beet-root at the Irish price of 15*s.* 6*d.* per ton, or the Essex price of 19*s.* per ton, refined sugar to sell at 28*s.* per cwt.?—the calculations on this point which had been most relied on were two in number, that of Mr. William K. Sullivan, Chemist to the Museum of Irish Industry in Dublin, and that of M. Paul Hamoir, of the firm of Serret, Hamoir, Duquesne and Co., the largest manufacturers of beet-sugar at Valenciennes, and dated April 18, 1850. These estimates were as follows:—

Mr. Sullivan's Estimate for Ireland.	£
60,000 tons of beet at 15*s.* per ton	45,000
Cost of manufacture at 9*s.* per ton of beet	27,000
Total outlay...	72,000
Produce, 5 per cent. of sugar at 28*s.* per cwt.	93,000
Estimated profit...	£21,000

Same Estimate applied to Essex.	£
60,000 tons of beet at 19*s.* per ton	57,000
Cost of manufacture at 9*s.* per ton of beet	27,000
Total outlay...	84,000
Produce, 5 per cent. of sugar at 28*s.* per cwt.	93,000
Estimated profit, only...	£9,000

M. Paul Hamoir's Estimate for France.	£
60,000,000 kilogrammes (61,607 tons) of beet at 16 francs (12*s.* 11*d.*) per 1000 kilogrammes (one ton nearly)	38,400
Cost of manufacture nearly 13*s.* per ton of beet	39,900
Total outlay...	78,300
Produce, 4½ per cent. of sugar at 39*s.* per cwt.	114,000
Estimated profit in France...	£35,700

Same Estimate applied to Ireland.	£
60,000,000 kilogrammes of beet at 15*s.* 6*d.* per ton	46,080
Cost of manufacture nearly 13*s.* per ton of beet	39,900
Total outlay...	85,980
Produce, 4½ per cent. of sugar at 28*s.* per cwt.	81,844
Estimated loss in Ireland...	£4,156

Same Estimate applied to Essex.	£
60,000,000 kilogrammes of beet at 19*s.* per ton	56,468
Cost of manufacture nearly 13*s.* per ton of beet	39,900
Total outlay...	96,368
Produce, 4½ per cent. of sugar at 28*s.* per cwt.	81,844
Estimated loss in Essex...	£14,524

From these simple calculations it appeared at once, that by only introducing into the estimates the Irish and English prices of beet-root and of refined beet-sugar,

the result was so varied as to turn a profit of £35,000, at the French prices, on a capital of £78,000, into a loss of £4,000 at the Irish prices, and a loss of £14,000 at the Essex prices. It followed therefore that the French estimate did not, as had been alleged, corroborate Mr. Sullivan's estimate; on the contrary, it showed how fallacious it was to reason from the success of the manufacture in France to its success in the United Kingdom, without taking into account the differences of the prices of beet-root and of refined beet-sugar in both countries; the differences in economic conditions between the two countries being alone sufficient to make that which was profitable in France unprofitable here.

The manufacture of beet-sugar had been first commenced in France when the continental system of Napoleon and the retaliation of England had almost excluded cane-sugar from France. From that time to the present beet-sugar had always had the protection of an artificial price (the present price being 39s. per cwt. in France as compared with 28s. per cwt. in this country). In every other country in the world where beet-sugar had been produced, it had the protection of an artificially high price. The conclusion was manifest, therefore, that from any calculations yet submitted to the public, it appeared that the manufacture of beet-sugar could not be profitably carried on in the United Kingdom.

On the Duties of the Public in respect to Charitable Savings-Banks. By Professor W. Neilson Hancock, *LL.D.*

The Professor said there were three kinds of savings-banks—joint stock, government and charitable savings-banks. The characteristics of the latter were, that the responsibility of management was divided between the Government and the trustees, and that neither of these parties were necessarily liable for the acts of their clerks. The savings-banks of the United Kingdom were of the third class; and the question which he proposed to discuss was, what was the duty of the public with regard to such institutions?

The charitable savings-banks were of recent origin, having arisen since 1800. The first legislation with respect to them took place in 1817; but the principal Act of Parliament on the subject was that passed in 1829. In this Act, the divided responsibility between the Government and the trustees was plain. The trustees had the appointment of clerks and the receipt of the deposits. The National Debt Commissioners had the entire management of the investing the deposits, and they could require an annual account from the trustees, and issue orders to stop any bank disobeying instructions. As to the liability of the Government for the acts of the clerks, it is plain that as they were appointed by the trustees, the Government was not liable for any money paid to a clerk but not invested in the names of the Commissioners.

As to the liability of the trustees for the acts of the clerks, they were at first liable to the extent of their whole property. In 1829 their liability was limited to their own acts and to the cases where they were guilty of wilful neglect. In 1844 they were freed from all liability, unless they declared in writing that they were willing to be liable, or unless they actually received the money themselves. Several failures having taken place in Ireland, in 1848 the exemption from liability of Irish trustees was repealed, but they were allowed to limit their liability to any sum exceeding £100. On the renewal of this act in 1850, although failures had taken place at Rochdale and Scarborough, it was not extended to England.

From the objects for which savings-banks were established, it was manifest that the whole success of these institutions, as a means of encouraging a habit of saving, depended on their affording a perfectly safe place of deposit; and their success in making the poor take an interest in the preservation of the public credit, depended on the public credit being strictly observed towards themselves; the whole success of savings-banks therefore depended on the security which the depositors had for their money. This could be best tested by the history of the Cuffe Street savings-bank in Dublin.

The Cuffe Street bank was founded in 1818, under influential patronage. In 1826 the trustees suspected the honesty of the actuary, and it took them five years to find out whether he should be trusted. In 1831 they found out his dishonesty by discovering defalcations to the extent, as they thought, of £1000. They applied

to the National Debt Commissioners on this emergency, and Mr. Tidd Pratt was sent to Ireland. He awarded £7000 to be paid by the trustees, and that £4000, claimed by the depositors, was not a legal charge. He advised that this latter sum should be paid out of future profits, and that the trustees should carry on the bank, as the future surplus would realize enough to pay all deficiencies. Mr. Pratt thought that the defalcations did not exceed £4000. The trustees, instead of waiting for future profits, paid the £4000 at once out of the incoming deposits; they also omitted to post the annual account, as required by law, from 1831 to 1848, and during all that time, their accounts, as furnished to the Commissioners of the National Debt, showed a deficiency. In 1838 the defalcations of the actuary were ascertained to have been at least £25,000. The bank continued, though insolvent during all this time, to possess public confidence until 1845. The Act of 1844 having relieved the trustees from liability, one of them disclosed the insolvency of the bank. A run followed, in which £200,000 was paid, leaving only £60,000 in the hands of the trustees, and which would have compelled the bank to stop payment had not the Chancellor of the Exchequer (Mr. Goulburn) allowed the bank to draw a larger sum than the regulation of the Bank of Ireland then permitted. When the run stopped, the depositors replaced their money, and the bank continued in operation until 1848, when another run took place, in which they paid away all but £90, leaving a loss of £60,000 on the depositors.

The trustees were relieved from legal liability by the Act of 1844. They said they were not morally responsible, in consequence of Mr. Pratt's advice in 1831, and the Chancellor of the Exchequer's allowance of the one draft in 1845. The Government said that *they* were not responsible, as Mr. Pratt was not an executive officer. After a long parliamentary investigation, by a vote of the House of Commons the depositors received £30,000, or 10*s.* in the pound.

From this case it appeared, first, that the character of the clerk was no security, as the Cuffe Street clerk had the highest character. It appeared, 2ndly, that the security given by the clerks was no protection. 3rdly, that the character of the managers and trustees did not secure the depositors, neither did their limited liability. The same case showed that no reliance could be placed on the appointment of auditors, or on any system of mere cheques. As it thus appeared that there was no real security for the depositors in charitable savings-banks as now constituted, the duties of the public in respect to these institutions were manifest:—1st. That those who advised the poor to deposit their savings in these banks should understand what security they recommended the people to trust to. 2nd. That trustees who were convinced that there was no real security, should have the banks they were connected with wound up and the depositors paid off. 3rd. That the public as legislators should provide for the removal of all impediments to banks of deposits being established for the poor by private enterprise, and for the formation either of government banks with government security, or of charitable banks with unlimited liability of the trustees; and put an immediate stop to the half-charitable, half-government institutions where there was no real security.

Should Boards of Guardians endeavour to make Pauper Labour self-supporting, or should they investigate the Causes of Pauperism? By Professor W. Neilson Hancock, *LL.D.*

The Professor commenced by showing that the history of the Irish famine had completely established the necessity of a public and compulsory system of poor laws, both on moral grounds and as a matter of police. He next pointed out that the controversies respecting poor laws had arisen from taking too narrow a view of the subject.

The subject of public relief of pauperism really gave rise to questions in every branch of the social sciences, in moral philosophy, the science of government, jurisprudence, and political economy. As to the particular question proposed to be discussed in the paper, it had been suggested by the efforts of the Sheffield and Chorlton and other boards in England to make pauper labour self-supporting; by Dr. Alison's paper 'On the Employment of Paupers on Waste Lands' at the Edinburgh meeting of the Association, and by similar plans attempted by the Cork, Thurles and Banbridge Boards of Guardians in Ireland. On investigating this question, it ap-

peared plainly that pauper labour could not be made self-supporting, for four reasons:—1st. Because pauper labour was necessarily inferior to the labour at the command of private capitalists. 2nd. Because boards of guardians were entirely unsuited to act as capitalists. The failure of the cultivation of waste lands at King William's Town in Ireland by the Commissioners of Woods and Forests, and the failure of the Waste-Land Improvement Company, both showed how unsuited such an enterprise was to be undertaken by boards of guardians. 3rd. Boards of guardians must either lose all the most skilful paupers, or they would have to relax the tests of destitution to retain them, and so would lose more by the increase of pauperism than they would gain by any profit on pauper labour. 4th and lastly. Because, if pauper labour could be self-supporting, it would follow that communism would be more advantageous than competition; as paupers employed by a board of guardians were in exactly the position of a community on the system of St. Simon, and to become paupers they must have failed to support themselves by free competition.

It followed, therefore, from these considerations, that pauper labour could never be made self-supporting, and that industrial enterprises could never be successfully carried on by paupers.

The opinion that pauper labour could be made self-supporting had to some extent been caused by the common fallacy on the opposite side of supposing that paupers should be kept in idleness or at unproductive work. This fallacy had arisen from the mistake of believing that pauperism was caused by over-production, whilst it always arose from under-production, or production misdirected. But the moral and economical view of this question coincided. It was the duty of the guardians to keep those under their care actively employed, since nothing could be more demoralizing than a life of idleness, and nothing more calculated to weaken the force of the workhouse as a test of destitution, than making it a place for the indulgence of indolence. In an economic point of view, it appeared extraordinary how any one could believe that the wealth of a community would be increased by keeping a number of people in idleness.

As the task of making pauper labour productive was a hopeless one, it was the duty of all intelligent members of the community, and especially of guardians of the poor, to consider the wide field for exertion open to the philanthropist and the statesman in the discovery and removal of causes of pauperism.

In a paper 'On the Causes of Distress at Skull and Skibbereen during the Famine in Ireland,' which he had read at the Edinburgh Meeting of the Association, he had pointed out some of the causes of pauperism in Ireland. In other publications he had treated of the same subject; but beyond the subjects he had already noticed, there were large fields of investigation connected with sanitary arrangements, with the savings of the poor, with intemperance and immorality. The great advantage of a long-lived over a short-lived population in respect to wealth, especially the wealth consisting of human labour, had not been sufficiently dwelt on. The early mortality of the Irish labouring population was a great source of pauperism amongst them. Every improvement in sanitary arrangements would lead in the most certain way to an increase of wealth and a diminution of pauperism. The want of a perfectly safe place for the investments of the poor was another prolific source of pauperism. He had shown in another paper read at this meeting, that the present half-government and half-charitable savings-banks afforded no adequate security, and although this subject had been investigated for some time no practical good had been done.

Again, could nothing be done with those large sources of crime, intemperance and immorality? It might be that nothing could be done directly, but could nothing be done indirectly? Was any one warranted in saying, without investigation, that nothing could be done? Would not the mere inquiry (if conducted in a proper spirit) into the nature and extent of these evils and into their causes, be attended with beneficial results?

If rightly considered, it would appear that all social evils and all defects in our institutions were to some extent causes of pauperism. The effects of these evils were shifted from class to class, until they came upon those in the lowest place; but this class had to bear them. He then showed that it was the especial duty of boards of guardians, as a department of government, and as the department most directly con-

nected with pauperism, to institute careful inquiries into the causes of pauperism in their respective districts. By an enlightened conception of their duty in this respect, and by a conscientious discharge of it, boards of guardians would do infinitely more for the diminution of poor-rates, and for the effectual removal of pauperism, than they would ever effect by the hopeless task of attempting to make pauper labour self-supporting.

The careful conducting of such inquiries, if undertaken from a sense of duty, and if carried out with the single-minded object of arriving at truth, would have a most salutary influence on the entire administration of the poor laws. It would encourage a spirit of enlightened benevolence, and put a check to the heartless selfishness that was too often avowed and even carried out in poor-law administration; such selfishness as was manifest in the endless disputes about the settlement of paupers in England; such selfishness as led to the transmission of paupers from England and Scotland to Ireland; such selfishness as led men to advocate any scheme of emigration, of law of settlement, of arranging electoral divisions, provided it ended in what was called "getting rid of the paupers," or provided it forced some one else by an extra stimulus on his self-interest, "to get rid of his paupers." Nothing would be so well calculated to check such selfishness and to secure the adoption of sound arrangements for the future, as for those immediately connected with the administration of the poor law to undertake a comprehensive and enlightened investigation into the causes of pauperism.

An Investigation into the Question—Is there really a want of Capital in Ireland? By Professor W. NEILSON HANCOCK, *LL.D.*

The Professor commenced by explaining that the phrase "want of capital," as used by Sir George Nichols, Mr. Campbell Foster, Mr. Montgomery Martin, and other writers on Ireland, really meant a deficiency in the supply of capital in proportion to the demand for it. He noticed the erroneous opinions that capital is synonymous with money, that capital is accumulated labour, that labour is capital, and that land is capital. The errors respecting the consideration of labour and land as capital were not mere verbal mistakes, but involved scientific, intellectual and moral evils. It was the duty of scientific writers to adhere to the established nomenclature of any science, the conclusions of which were used in discussing public questions. In political economy, one of the chief results that had been established beyond controversy, was the analysis of the price of a commodity into wages, profit and rent, founded on the distinction of the instruments of production into three—labour, the use of capital, and land; it was therefore a serious error to confound these, as no one of them could supply the place of another. A labourer could not use land as a spade or a plough, or as food; neither could he subsist until harvest on labour, unless some capitalist had food saved to give in exchange for his labour. Any confusion as to these fundamental, intellectual conceptions, placed a writer under serious disadvantages for understanding or discussing a question. The moral evils of confounding labour and land with capital were equally great. This error had led to the most unjust attacks on the character of the poorer classes in Ireland. Thus, when the small holders of land found it difficult to get employment from the abundance of labour, when the tenure of their farms was so precarious that these tenants could raise no capital on the security of their farms, they had been flippantly told that they did not want capital, since labour was capital and land was capital, and therefore that the bad cultivation did not arise from any cause but their own indolence.

The most conclusive proof that the poorer classes in Ireland would save if their wages enabled them to do so, was afforded by the large remittances sent by Irish emigrants in America to their relatives in Ireland. This subject had been first noticed by Mr. Robert Murray, chief Manager of the Provincial Bank in Ireland. In a letter to Sir Robert Peel in 1847, he showed that these remittances had been increasing for ten years prior to 1847, and in that year amounted to 125,000*l.*, in 24,000 distinct remittances.

Having thus disposed of ambiguities and erroneous theories, he then proposed to ascertain whether the supply of capital was deficient in proportion to the demand for it by the following tests:—first, by observing the exports and imports of capital;

and secondly, by observing the changes in the rate of profits. As to the exports and imports of capital between Ireland and England, it appeared that the public funds might be transferred from the Bank of England to the Bank of Ireland and back without expense, and that such transfers were very frequent. The portion of the public debt on which interest was paid in the Bank of Ireland might be assumed to belong to Irishmen. Now, Mr. Stanley, the Secretary to the Irish Poor Law Commissioners, in his Prize Essays on Ireland, had shown that from 1824 till 1831 the quantity of public funds transferred to Ireland was about 14,000,000*l.*, and the quantity in the same time transferred from Ireland to England was about 6,000,000*l.*; leaving 8,000,000*l.* funds held by Irishmen in 1831 more than in 1824, and implying an export of capital of about a million a year for these eight years. Dr. Longfield, in his address to the Dublin Statistical Society in 1849, had shown that in eight years ending in 1848, about 11,000,000*l.* worth of public funds were transferred from England to Ireland, and about 4,000,000*l.* from Ireland to England; leaving 7,000,000*l.* more funded property held by Irishmen in 1848 than in 1841, and showing an export of capital from Ireland to England of 7,000,000*l.* in those eight years, including three years of the famine. In 1849 the transfer of funds from England exceeded that from Ireland by about 300,000*l.* In 1850, for the first time for many years, the export of capital from Ireland was stopped. In that year the funded property transferred to Ireland was 1,160,000*l.*, and from Ireland to England 1,970,000*l.*; giving a diminution in Irish funded property of 810,000*l.*, and showing an importation of capital into Ireland of that amount. The result of the long-continued export of capital from Ireland to purchase funded property, was shown by the quantity of that property held by Irishmen, which was as follows:—

Irish Courts of Equity	£3,900,000
Irish absentees paying income tax	3,100,000
Residents in Ireland	31,000,000
Total	£38,000,000

When it thus appeared that Irishmen had 38,000,000*l.* worth of funded property, which could any moment be converted into money, it was preposterous to assert that the supply of capital in Ireland was deficient in proportion to the demand for it. Accordingly, as soon as the parliamentary title of the Encumbered Estates Commissioners afforded an opportunity for the safe investment of capital in Ireland, such capital was invested to the extent of 1,000,000*l.*, up to November 1850, in the purchase of estates, besides what was invested in improvements. It appeared too that the purchasers were chiefly Irishmen; for out of 587 purchasers, only 30 were from England or Scotland.

The second and more complete test of the supply of capital in any country in proportion to the demand for it was, the changes in the rate of profit. It appeared that the price of the funds had for many years been nearly the same in Ireland as in England; and consequently that the rate of profit, as distinct from insurance against risk and wages of superintendence, was practically the same in England as in Ireland. Hence the supply of capital in proportion to the demand for it was the same in England as in Ireland; so that there had not been for many years any want of capital in Ireland, as it was conceded that there was no such want in England. The conclusion thus arrived at was of great importance, and led to results very suggestive of future thought and investigation:—

1st. It showed the utter futility of all plans like Mr. Montgomery Martin's all-sufficient circulating medium for improving the condition of Ireland by tampering with the standard of value.

2nd. It showed that, however deficient capital might be amongst many of the pauper tenantry and encumbered landlords, the scanty application of capital to the cultivation of land in Ireland did not arise from any deficiency of capital amongst Irishmen.

3rd. It showed the absurdity of supposing that estates could not be bought, land cultivated, or good done in Ireland without the introduction of English capital and English capitalists.

4th. It showed the necessity of looking beyond the superficial theories of the past

to account for this remarkable state of Ireland,—that there were thousands of able-bodied labourers unable to get employment, thousands more on scanty wages of 6*d.* and 8*d.* a day, millions of acres of improveable land lying wholly waste, millions more badly cultivated, whilst more than 20,000 capitalists, all Irishmen, found it for their interest to lend 38,000,000*l.*, at about 3¼ per cent. to the government of the richest country in the world.

On the Influence of Discoveries in Science and Works of Art in developing the Condition of a People, as indicated by the Census Operations of the United States. By J. C. G. Kennedy.

The author stated that the Government of the United States had adopted the best system, yet made available by any people, for eliciting those facts necessary for the understanding of their true condition. The United States were the first to incorporate the principle with their fundamental law. Other nations had taken censuses previous to them, but the object of such was mainly to learn their own availability in a military point of view, or to know what amount of imposition might with safety be placed on estates so as barely to preserve and not entirely destroy them; but the Government of the United States was actuated solely by the desire to know the true condition of the people, in order to legislate with wisdom, and to know in what things to encourage continuance, what error to abate, what abuse to correct. He showed, that in 1790 they confined their inquiries to the number of the people of different colours and condition, as free and slave; twenty years after they included statistics relative to agriculture, manufactures and commerce; now at the distance of sixty years, they include, *by a law made permanent*, a collection of nearly all those facts the development of which will illustrate their exact condition, as to numbers, white, black, and mulatto, male and female, free and slave, at every age. The present census, when fully compiled, will give the number of families, the number of dwelling-houses, and the occupations, professions and trades of all persons; the birthplace of each individual, the number married, widowed and single, the number attending school, the number unable to read and write, the blind, deaf and dumb, the insane, the idiotic, the paupers and convicts. With reference to the slave population, they take the ages, sex, colour, the number voluntarily manumitted, the number who have manumitted themselves, with the deaf and dumb, blind, insane, and idiotic. They take an enumeration also of those who have died, their age, sex, colour, condition, birthplace, profession or occupation, disease or cause of death, and the number of days ill. In connexion with these statistics, they procure an account from each county in the United States of its geological formation, its soil, rocks, minerals, mountains, marshes, rivers, timber; its date of settlement, its date of organization, the place of nativity of its first settlers, its canals, plank turnpikes, and railroads, telegraph wires, banking institutions, insurance offices, their capital and dividends.

They enumerate the acres of improved and unimproved land belonging to each farmer, its value, the value of his farming implements and machinery, the numbers of each variety of live stock, its value and the product of his farm, specifying the quantity of each variety. They enumerate the various manufactures and trades, with the amount of capital invested in the business, the quantity and kind of raw material used, the value of each, the kind of power used, the number of male and female hands employed, the wages paid, and the various productions in quantity, kind, and value. They take the aggregate value of all personal and real estate of each county, the kind and amount of taxes, the number of colleges, academies and schools, the teachers and taught, with the revenues. They take an account of the libraries, newspapers, and churches, with their number, character, circulation, and value respectively.

These elementary facts, it was contended, formed the only true basis of knowledge with respect to a people, and that while they illustrated the exact condition of that people in wealth, numbers, natural increase, health, longevity, and general comfort in different locations at the same moment, they were so taken as to admit of combinations of interesting tabular arrangements rich and varied, for the use of the moralist, philosopher and statist of all countries.

Many of the developments of the census already made known were glanced at. 1st. The influence of the foreign population in their midst, which he contended was of so pernicious a character, "that common humanity required of foreign nations more attention to the education of their indigent population, if the subject was viewed only as affecting the destinies of their people when scattered over the new world, setting *aside entirely* its value to the peace, welfare, and happiness of those at home." Mr. Kennedy affirmed that ignorance multiplied crime, and adduced facts to prove, that to the ignorance and degradation of the foreign population in America could they point as productive of the most terrible evils to themselves, and as the cause of nearly all the pauperism and crime which could be shown to exist in the northern states.

He took a view of the proportion between sexes and colours, and the relative increase of each, showing from the facts developed that the coloured population would become rapidly extinct if immediate emancipation of slavery was to occur.

He alluded to the advances made in the seeking out and providing for the deaf and dumb, blind, insane and idiotic, paupers and criminals, and gave a gratifying account of their progress. He dwelt at some length on the reciprocal advantages arising from their protection of their manufactures, to their morals and agriculture, estimating the capital invested in the former at 400,000,000 dollars, but that their agricultural resources would justify a double amount of investment in manufactures, to which they looked as the natural supporter of agriculture in all time to come; that while England could purchase cheaper from the continent, they need not rely on her as a great consumer; and that as things now were, the gold they dug in California was "silently but surely passing through their own mints into those of Europe for recoinage, and thence into the coffers of European capitalists."

He next alluded to their principle of taxation, that on real estate, as the proper one, and the only rational one, to induce persons to bring into cultivation the immense bodies of wild land being accumulated by capitalists. In giving an account of this important branch of their investigations, he dwelt on the extent and character of education bestowed upon the youth of America, and exhibited its influence on their morals and the good of the state, traced the origin of provision for education in the several states, and their movements in its behalf up to the present time, when there were in the schools of America two and a half millions of scholars and a school fund of 30,000,000 dollars.

On the best Means of ascertaining the Number and Condition of the Infantile Idiots in the United Kingdom. By Edw. J. Tilt, *M.D.*

At the last Meeting of the British Association at Edinburgh, it was suggested in a paper read by Dr. Coldstream, "that it was advisable to obtain statistical information as to the number of idiots in Great Britain." The knowledge to be thus obtained is still most desirable, and requisite to the due carrying forward of the work of forming institutions for their relief. Since the last Meeting we have renewed proofs that the Swiss cretin is in many cases capable, not only of relief, but of cure. The late visit of Dr. Guggenbühl, the founder of the institution on the Ohendberg, has caused fresh observations made on this subject to be made known and confirmed. He was unable to remain in England to attend this Meeting, but he is very anxious that all possible research should be continued concerning the numbers of those afflicted with the malady in this country, and the degree of idiotcy to which they are reduced. He made several journeys through different counties of England, the result of which has been partly made known in a "Letter addressed to Lord Ashley on some points of Public Concern and Christian Legislation." Although the disease exists under different forms in different countries, yet in all its states it must always be considered as the greatest calamity which can afflict a family or an individual; and each country is deeply concerned in ascertaining how far it may be relieved or cured, as well as in what manner it may be averted or prevented by timely care. That it is a question peculiarly affecting the present attention to sanitary measures both in towns and villages is undoubtedly evident. It may be denied by some that any true cretins exist in England, although Dr. Guggenbühl relates that "of 500 idiots lately discovered in Lancashire, a considerable number are marked with the character of cretinism; in

the village of Settle I detected some cases nearly identical with many of the cretins of the Alps. In the village of Chiselborough in Somersetshire, most of its 350 inhabitants are afflicted with goitre, are very subject to deafness, imperfect utterance, and low degree of intelligence, which in as many as 24 individuals descends to absolute cretinism." Idiotcy is generally allowed to be *incurable*, whilst cretinism has been often *cured*, yet in all cases idiots are capable of some kind of amelioration. This has been proved by Dr. Howe of Boston, United States, and the three institutions founded within the last few years in this country. At Park House, Highgate, and at the branch institution at Essex Hall, Colchester, great relief has been afforded and beneficial change effected in the state of the poor idiot children in regard to health, behaviour, happiness, comfort, and even intelligence, for in many cases they have been enabled to occupy themselves in various useful ways. The work of restoring the cretins has been carried on in Switzerland by one devoted individual during the last ten years. Similar establishments are now rising up in several parts of the continent. Three houses have been opened in this country for the poor idiot, but the number of applicants far exceeds the vacancies; to ascertain the numbers, and to provide institutions, is now a work to be carried on, every effort hitherto made having proved successful as far as the nature of the case admitted of relief or cure.

In the discussion on this paper, Mr. Kennedy (Director of Statistics at Washington) pointed out that in the last United States Census, the name and residence of every idiot in the States was recorded, so as not only to show the number of idiots, but also to give to charitable institutions the means of relieving them. Mr. J. Hancock and Mr. Gowing also took part in the discussion.

A Mathematical Exposition of some Doctrines of Political Economy. By the Rev. W. Whewell, *M.A., D.D., F.R.S.*

MECHANICAL SCIENCE.

On the Duplex Rudder and Screw Propeller. By Capt. Carpenter.

The models represent views of a screw steamer constructed on what, after much consideration, I have determined to call the duplex principle, namely, with two rudders and two propellers for improved steering and propelling. To construct a vessel on this plan, the dead wood, stern-post and rudder are removed from their former position, and the midship keel, which before was placed in a straight and horizontal line from stem to stern, is now made to rise up on a graduated scale from the midship section to the water-line of the midship part of the stern, where it terminates. The additional keels lie in a parallel line with the midship keel, but placed at a distance of two or more feet, according to the size of the vessel, on either side of it, terminating near to the midship section in the fore-part, and in a line with the former stern-post in the after-part. A stern-post is placed at the end of the additional keels, and upon each of them hangs a rudder, Framework is carried down to these keels in proper architectural lines for speed, at the same time connecting the frame together, so that the strength of the vessel is increased in the after section, where it is most required in a screw steamer. Between this framework, a channel is formed for the water to pass away freely in a direct line with the midship keel. A screw propeller works in an orifice in each framework on the common arrangement. One of the propellers is a little more aft than the other to allow fullplay to both, and yet economize space in the mid-channel. The propellers turn each of them towards the centre line of the vessel for propelling and the reverse way for backing. A steering-wheel is placed on the deck in the usual way, and connected with the tillers, which move the rudders together in parallel planes, or separately, as may be required. The propellers can be lifted out of the water, for sailing, by means of a simple apparatus, which is placed on the deck for that purpose, or they may be feathered if pre-

ferred. This arrangement is found by experiments to have the best effect for steering and propelling, although this new form of vessel admits of many variations of adapting the ordinary propeller or other propellers to it; for example, the common paddle-wheel may be placed on the sides of the vessel in the usual way, or the common screw propeller may be placed between the framework, or sailing vessels may be constructed on this principle. The advantages of the duplex rudder and screw propeller may be considered under three heads: first, as regards the two rudders; second, the two propellers; and third, the construction of the vessel. To explain the advantages fully of having two rudders to a vessel instead of one, it will be necessary to refer to what has actually taken place practically on a model, as I have not been able to make any experiments on a larger scale up to this time. The duplex rudder has the power of turning the vessel about in the extremely short space of less than once and a half of her own length, with the helm put hard over on starting, and going full speed all the time till the circle has been completed. A single rudder of the same size placed in a line with the midship keel on the same model, and propelled in the usual way with a screw propeller in the dead wood, will not turn a vessel about in less than four and a half times her own length under similar circumstances. This fact shows the infinitely superior power and command there is over a vessel at all times with the duplex rudder in comparison with that in general use, and consequently that accidents by collision would be in a great measure prevented, and the general safety of steam-vessels better secured by its adoption. Moreover, as either of the rudders on the duplex principle can be used to steer with singly, it is evident that, in the event of damaging either one or the other, the vessel would be still under command, and therefore safe from immediate danger, when a vessel fitted with a single rudder would be in a perilous position.

A proposed Railway Communication from the Atlantic to the Pacific in the Territories of British North America. By ALEXANDER DOULL, *C.E.*

The author prefaced his notice of the railway by a general view of the great public questions which its construction involved, and remarked on the nature of Mr. Whitney's project for the construction of a railway from Lake Michigan to the Pacific, through the territory of the United States, which has deservedly attracted considerable attention in England.

The recent introduction of railways, and the application of steam power to navigation, has very much altered, and will no doubt still further alter, the systems of travelling, and consequently the great leading feature of the day is the perfecting of expeditious and cheap modes of travelling; and as there ever will exist a physical impossibility of travelling as expeditiously, as comfortably, and as safely on the waters of the ocean as on land, every effort will no doubt be made to shorten the distance by sea, and to accommodate the land communication to the new arrangement.

Halifax in Nova Scotia will therefore possess considerable advantages over New York, in the United States, as the Atlantic terminus of a railway communication across the continent of America, inasmuch as a line drawn from Cape Clear in Ireland to New York, would pass very close to Halifax; and thus the whole of the coasting distance of the sea passage from Halifax to New York would be saved.

From Halifax to Quebec the line would follow the course selected by Major Robinson of the Royal Engineers, and from Quebec it would be directed, as nearly as circumstances would permit, to the northern extremity of Lake Superior, crossing the Ottawa at the most convenient point below Lake Temiscaming.

From Lake Superior the line would pass to the north of the Lake of the Woods, which portion of its route would pass through a rich mineral and agricultural district. Continuing through a very favourable country to the important Red River settlement, and along the extended prairies south of the river Assiniboine, which portion of the line for a considerable distance would pass nearly along the water-shed of the country, there would be no bridges of any importance to construct; continuing from Brandon House to Red-deer River, still keeping near the water-shed of the country, and passing through a district where coal is found to crop out in the banks of the rivers, and consequently easily worked.

The passage of the Rocky Mountains is doubtless a point of considerable import-

ance, and one upon which it must be admitted there are no data for the formation of any definite plan. All authorities, however, concur in viewing this barrier as much less formidable on the British than on the United States territory.

Mr. Isbister is said to have found the rivers Athabasca and Saskachawau flowing through alluvial formation, and that in their vicinity the Rocky Mountain chain had lost its identity, and was reduced to inconsiderable elevations of from 600 to 700 feet.

Having crossed the Rocky Mountains, either by ascending to the summit upon the lateral spurs, or passing through by a tunnel, as circumstances might determine, the line would take the direction of Frazer's River to the Pacific Ocean.

The numerous and spacious harbours in the vicinity of Vancouver's Island, together with a rare combination of maritime advantages and an abundant supply of coal, point to this spot as the site of the future capital of the West.

At first sight the selection of this line may appear a very formidable undertaking, and doubtless it will require both energy and skill. The operation being rather an extensive one, the most judicious plan would be to cut up the distance into sections by ascertaining and fixing the points at which the principal obstacles, such as rivers and mountain ranges, would be crossed most easily. These sections would then be treated as integral lines, although forming portions of the whole, and thus the operation would become much more manageable.

Nearly the whole range of country through which the proposed line would pass is admirably adapted for the purpose of affording numerous points at which to form small settlements and to commence the work at several places at the same time, in consequence of the existing facilities for water communication, and the many small settlements already in existence.

To construct an extensive railway, beginning at one end and working continuously to the other, would entail much additional expense and render the progress very slow.

The abundant supply of building materials which are found along the whole course of this line, the rich agricultural and mineral districts, affording employment to the various classes of emigrants, and also being the shortest possible route from Europe to China across the great American continent, seem to point to this district as the natural position of a land communication between the Atlantic and Pacific Oceans.

In reference to the various and almost boundless resources of the territory under consideration, better authority cannot be desired than that furnished by the celebrated report of the Earl of Durham upon the affairs of British North America.

But however great the resources of any country may be, without the means of internal communication these resources must remain undeveloped. So intimately does the prosperity of any country depend upon the introduction of roads, that this one class of improvements has always been held as an unerring criterion of the degree of civilization and prosperity to which it has attained.

With respect to the ways and means by which this gigantic project is to be carried out, it has been stated that the construction of the first portion, amounting to about 700 miles, has been guaranteed by the Imperial Government; and in reference to the remaining portion, the varied circumstances of the territory passed through—dense primæval forests of the best timber, rich mineral districts, already partially occupied, and extensive tracts of agricultural and grazing land, alternating along the proposed route,—clearly indicate the varied resources by which the road must be constructed.

Those portions passing through the primæval forests of timber of superior quality, must be paid for by the timber upon the ground, and also the land when cleared, and that not by cutting down the timber in the first instance, but by merely cutting a passage for the railway, and opening out an extensive traffic in timber, superseding altogether the present laborious, unmechanical, barbarous system of "lumbering," which destroys a great proportion of the timber, and damages to a considerable extent the remaining quantity.

The mineral and agricultural districts must in the same manner be made to pay for the construction of the line passing through them.

The breadth of land necessary for this purpose can only be ascertained by a careful examination of the several localities, comparing the difficulties of construction with the remunerative character and capabilities of the particular district.

On the Construction of Iron Vessels exposed to severe strain. *By* William Fairbairn, *C.E., F.R.S.*

In the construction of vessels, such as boilers, pipes, &c., exposed to severe internal pressure, it is desirable to obtain some knowledge of the strength and condition of the material used, and some fixed rules calculated to enable us to judge with accuracy as to the disposition of the parts in order to apply the greatest strength in the direction of the greatest strain, and, in fact, so to dispose of the material in order that every part of the vessel shall balance itself in its power of resistance when subjected to uniform pressure.

To attain these objects, the author gave the results of his experiments on the resistance of malleable iron plates first announced to the British Association, and subsequently published in the Transactions of the Royal Society. These experiments were originally undertaken to determine the strength of metal plates, beams, and angle-iron, as applied to ship-building; and they have since been continued, from time to time, for the equally important purpose of improving the construction of malleable iron bridges, boilers, and other vessels, such as caissons and sheet-iron pipes, which are now coming into more general use for pump trees and other articles connected with mining.

In order to acquire satisfactory data on the strength of the material employed, a variety of plates from Low Moor, Staffordshire, and other parts, were submitted to direct experiment; first, by tearing them asunder in the direction of the fibre; and secondly, across it. The tensile strength per square inch was ascertained to be as follows:—

		In the direction of the fibre.	Across the fibre.
Yorkshire plates ..	=	24·26	26·93
Derbyshire plates	=	21·68	18·65
Shropshire plates	=	22·82	20·00
Staffordshire plates	=	19·56	21·01
	Mean in tons	22·16	Tons 22·29

From this it will be observed that there is no difference in the strength of iron plates, whether torn in the direction of the fibre or against it; and this uniformity of strength probably arises from the superior manner in which that article is now manufactured.

The experiments would however be imperfect as regards construction, if they had not been extended to the process of riveting; and on this point our information has been of the most meagre description. Until of late years many of our numerous constructions have been conducted under the impression that the riveted joint was not only strong, but absolutely stronger than the plate itself; whereas more than one-third of the strength is lost by that process.

To prove the fallacy of these views, it was ascertained by experiment that the strength of iron plates, as compared with their riveted joints, was not only weakened to the extent of the quantity of metal punched out to receive the rivets, but that in the following ratios, viz. as 1000 : 700 in the double-riveted joint, and 100 : 560 in the single-riveted joint.

From the above facts practical formulæ have been deduced to show, that the maximum resistance of single-riveted plates does not exceed 27,000 lbs. to the square inch; but taking into account the crossing of the joints and other circumstances peculiar to sound construction, 34,000 lbs. or 15 tons per square inch has been found to be the maximum strength of riveted plates, such as those used for boilers and similar constructions.

In conclusion, attention was directed to several important improvements in connection with the construction of steam-boilers, by the introduction of gussets, to strengthen the flat ends and retain them in shape. After noticing that all boilers should be of the cylindrical form, Mr. Fairbairn observed that when flat ends are used they should be composed of plates one-half thicker than those which form the circumference. The flues, if two in number, to be of the same thickness as the exterior shell, and the flat ends to be carefully stayed with gussets of triangular plates and angle-iron, connecting them with the circumference and the ends.

The use of gussets is earnestly recommended as being infinitely superior to and more certain in their action than stay-rods. They should be placed in lines diverging from the centre of the boiler, and made as long as the position of the flues and other circumstances in the construction will admit. They are of great value in retaining the ends in shape, and may safely be relied on as imparting an equality of strength to every part of the structure.

On Railway Chairs and Compressed Wood Fastenings. By Charles May, *F.R.A.S.*

The author brought these observations forward with a view to giving information to such persons as might incline to visit the manufactory of them at the Orwell Works, which would be open to any visitors to the British Association.

The chairs were those used upon narrow gauge lines with cross sleepers, and the mode of casting effected great accuracy, so that each was practically a counterpart of the rest; and so extensively had this system been adopted, that more than fifty railways had been supplied with them.

The fastenings are those pieces of wood called treenails and wedges; the former being used as nails to fasten the chairs to the sleepers, and the latter to secure the rails in the chairs.

Mr. May described the structure of wood as a bundle of tubes of irregular shape, which, when emptied of the sap by drying, might be squeezed together into a smaller bulk, just as a bundle of leaden pipe might be compressed; but in the case of wood, which is elastic, it is found necessary to keep the compressing power on it for some time, or it would more or less re-expand; if, however, during the continuance of the compressing force, a small degree of heat is applied, the wood takes a "set," which is permanent as long as the article is kept dry; but the power of capillary attraction not being destroyed by the process, the fastenings, when used upon the railways, expanded like a cork driven into a bottle, and this kind of elastic fastening was found to produce not only increased security as compared with other modes of fastening, but also a smoother motion in the carriages.

The same mode of compression is adopted for the treenails of ships, and from a series of experiments made by a Committee appointed by the Admiralty, it appeared that these compressed treenails had 29 per cent. more transverse and 60 per cent. more adhesive strength than those in ordinary use; yet even these advantages had not secured their adoption.

On the Application of Chilled Cast Iron to the Pivots of Astronomical Instruments. By Charles May, *F.R.A.S.*

In laying before this Section a few observations on this subject, some preliminary remarks on the process of chill casting and its previous application to other purposes seem to be requisite.

"It has long been known that if a mould for casting iron be made of iron, or partly of iron and partly of sand, that portion of the casting which has run against the iron becomes what is technically termed 'chilled,' and is indicated by a white crystalline structure to a depth depending upon various conditions of temperature of the mould and the metal run into it, as well as of the chemical composition of the iron. The practical utility of chill casting depends on the fact, that the part thus rendered crystalline is of extreme hardness, nearly equal to that of hardened steel; whilst the remainder of the casting may be as soft as iron cast in the ordinary sand-moulds.

"The rationale of the effect thus produced is not well understood; cast iron is a compound of iron with variable proportions of carbon, and these proportions have not, as I believe, been yet reduced to anything like atomic order: some statements give as much as 15 per cent. of carbon in very soft pig iron, and such iron exhibits very little or no tendency to chilling. Practical experience is at present the only guide to the production of the desired effect; in some cases a very thin hard stratum is desired, in others a considerable depth; and this stratum may be varied from an almost imperceptible white line to half or three-quarters of an inch in depth, this latter

being required in the large rolls for making the finest thin sheet iron. Chemically speaking, cast iron and steel are of the same composition, viz. iron with a proportion of carbon; the proportion of the latter in cast iron being infinitely greater than in steel. Here I would point out a remarkable difference between chilled cast iron and steel. If the latter is heated red-hot and plunged into cold water it becomes extremely hard; if in this state it be again heated, it resumes its original softness; but if chilled iron be so treated it still retains its hardness. Whether this is caused by mere mechanical arrangement or by the chemical combination of the atoms, whether there be a metallic base of carbon in one case and not in the other, or by whatever these differences are caused, is far too little understood; the whole subject is one deserving the close attention of those whose pursuits enable them to study chemical analysis. Indeed, when we reflect on the fact, that without the peculiar properties of iron and carbon, civilization could not have been carried on, it does appear strange that the master-minds of the age have not acquired more knowledge of the relative action and combinations of these two substances. It would be foreign to our present object to enter upon the mode of manufacturing steel, but I may state the fact, that it is extremely difficult to procure any masses that are of uniform density, whilst chill cast iron is easily produced with large homogeneous surfaces, and this brings me to the main subject proposed for your attention, viz. the application of it to the pivots of astronomical instruments. About four years since the Astronomer Royal applied to my partners and self respecting the construction of the mechanical parts of a new meridional instrument, the size of which so greatly exceeded anything of the same kind, that it became a serious question of what material the pivots should be made: it was requisite that it should be both hard to resist wear as much as possible, and homogeneous to ensure that whatever wear took place should be uniform.

"The extensive use we make of chill cast iron suggested, that if the pivots were so cast with the body of the axis in sand mould and all run together, an instrument might be produced combining all the requisite qualifications. This has been successfully accomplished, and the great transit circle or meridian instrument is now at work in the Royal Observatory to the satisfaction of the Astronomer Royal, on whose designs the whole has been constructed."

After a rigid examination of the form of the pivots, the Astronomer Royal has concluded that no correction for the shape of the pivots is required. Specimens of trial castings for the pivots were laid before the meeting.

Description of an Improved Safety Valve. By James Nasmyth, *F.R.A.S.*

Mr. Nasmyth described his improved safety valve for steam-boilers, in which he sought to combine simplicity of construction and efficacy of action with the utmost security which a safety valve can afford against explosion arising from undue pressure. He prefaced his description by alluding to the main source of derangement and uncertainty in the action of safety valves as hitherto constructed, namely, the employment of a conical bearing surface in the valve and in its seat, which renders the use of a spindle and guide-socket requisite so as to constrain the valve to rise from its seat in a direction absolutely vertical to the seat or bearing. This guide-spindle to be of any service has to fit the socket in which it works with considerable precision, in consequence of which any mud or incrustation which may chance to get upon the spindle of the valve tends to prevent its rise and so far arrest its action. In order to remove this serious defect, a spherical bearing has been employed, which, by permitting the valve to fit its seat in any position, dispenses with the necessity of any guide or spindle. The grand feature in Mr. Nasmyth's improvement, however, consists in the peculiar mode by which a constant slight movement is given to the valve in its seat by employing the motion of the water during ebullition so to act upon the valve as to furnish the means of preventing its ever becoming set fast in its seat.

This important object is attained in the most simple manner by attaching to the bottom of the weight, which hangs down *inside* the boiler (and which weight is attached to the valve by an inflexible rod), a sheet-iron appendage, which dipping a few inches into the water, transfers the constant swaying motion of the water to the

valve in its seat, and so keeps it constantly free and ready to rise whenever the pressure attains the required force.

Mr. Nasmyth exhibited several diagrams drawn by the valve itself, which gave the most clear evidence of the existence and nature of the motion which the valve derives from the action of the water on the sheet-iron appendage before named. These diagrams were obtained by attaching a pencil to the top of the valve, and permitting it to draw upon a card such figures as resulted from the slight but incessant motion of the valve. The perfect action of this valve has led to its extensive adoption.

On a Direct Action Steam-Fan for the more perfect Ventilation of Coal Mines. By JAMES NASMYTH, *C.E., F.R.A.S.*.

Mr. Nasmyth exhibited drawings and gave a description of his direct action steam-fan which he had contrived and arranged for the purpose of improving the ventilation of coal mines. The fan is one of the most efficient and simple agents for moving great masses of air, and operating through the agency of centrifugal action; the quantity of air which it can draw in at its central opening is exactly equal to what it can blow out or distribute from its circumference; and although we are most familiar with the action of fans as *blowing* agents, yet the suction powers of fans are equally effective, and it is this suction power which Mr. Nasmyth proposes to employ as the means for the better ventilation of coal mines. In this respect the application of fans for the purpose in question is not novel; but the efficiency of these powerful and otherwise simple machines has been much impeded by the complex and troublesome apparatus which has hitherto been employed for transmitting the required high rotative velocity to them, such as by the use of straps, belts and pulleys, and other agents employed in converting the slow motion of a long-stroked engine into the high velocity of rotation required by such fans.

The chief feature of novelty in the fan proposed by Mr. Nasmyth, consists in the application of a short-stroke steam-engine working direct on to the spindle or axis of the fan, on the end of which the crank of the engine is placed; by this system of arrangement all intermediate gearing and machinery is done away with, and the power of the steam made to act in the most direct manner on the fan. The diameter of the fan described by Mr. Nasmyth is 6 feet, the stroke of the engine 4 inches; the diameter of the cylinder of the engine being 12 inches, this, worked with steam of a pressure of 30 lbs. to the square inch, produces a rate of motion on the fan of 650 revolutions per minute; and as the fan blades are 2 feet wide, the rate of discharge in cubic feet per minute is equal to 23,000; and as the ingress apertures at each side of the fan are in direct communication with the up-cast shaft of the mine, a corresponding quantity of air will descend the down-cast shaft and pervade the workings. An important advantage of this mode of ventilation will be, that the ventilating agent, namely, the fan, is at all times visible, open to inspection, being placed on the surface of the ground, and in that respect free from danger; and even in the event of any explosion in the pit, the means of reventilating is by its means at hand.

On an improved Apparatus for Casting the Specula of Reflecting Telescopes. By JAMES NASMYTH, *C.E., F.R.A.S.*

On a Method of condensing Steam in Marine Engines, at present employed in several Steam Vessels in the Bristol Channel. By JOSEPH T. PRICE *of Neath Abbey.*

It is well known that Boulton and Watt, when they took out their patent for their steam-engine, tried the effect of surface condensers, and proved the superiority of condensing by a jet of water in land engines; but it is also well known that at that period marine engines for giving motion to ships on rivers and the sea had not been used. Had marine engines been in use at that time, it may fairly be supposed that Boulton and Watt would not have omitted to show the adaptation of the cold water through which a vessel passes to the purpose of condensation and feeding the boiler with hot water freed from salt, &c.

The employment of muddy and salt water for condensation of steam and for maintaining a vacuum in marine engines is well known to be disadvantageous, so much of the power of the engine being employed in the process of exhaustion by the air-pump.

The application of the screw-propeller for a ship at sea has called attention to the means most simple and effective for obtaining for such propellers a rapid motion, whereby to ensure high speed for the ship.

These are among the considerations which have led to the discovery that the steam, after it has exerted its power on the piston, may be condensed instantly by being conducted into a receiver or receivers placed longitudinally within a vessel, and on each side, filled after the manner of tubular boilers, with metallic tubes inserted into metallic plates of ample substance to ensure perfect tightness, and each end of which is connected with the water of the sea or river by a bent tube and apertures made in the sides of a ship or vessel.

This method has been for several years adopted to great advantage.

"It was mentioned by myself to the Mechanics' Section of the British Association for the Advancement of Science two years since, when their Annual Meeting was held at Swansea, but it was named only incidentally in the course of some discussion on marine engines, and I am not aware that it has ever claimed the attention which further experience has shown it merits. I therefore avail myself of the occasion which is now presented to me to place before the view of the meeting facts fairly proved by the Neath Abbey Iron Company as makers, and myself as associated with them, and as an owner of several of these marine engines; that even high steam may be safely employed in such vessels in what, for facility of description, I will call locomotive boilers; that such steam gives a rapid motion to the piston, and that this action may be conveyed direct to the crank, giving motion to a shaft and propeller without any multiplying wheel; that the steam so employed may be condensed by being at once conveyed from the cylinder into the receiver within the vessel, furnished with metallic tubes, through which the water of a river or the sea shall rapidly pass; that such water so passing through the tubes of a receiver maintains coldness to a great extent in the interior of such receiver; that the steam passing from the cylinder into such receiver becomes instantly condensed, though still retaining heat enough for advantageously feeding the boiler with fresh water; that by these means little or no vacuum can be obtained independently of the power of the engine employed in other vessels in working the air-pump; that the water so condensed is again, by pumping, transferred to the boiler, and that thus the supply of fresh water taken in at starting serves, as far as I have proved it, for a voyage from port to port for one day; that hereby the boiler is kept free from salt or mud, and does not require to be blown out to clear it from salt, and thus time and power are further œconomized; and that under all these circumstances a higher speed may be acquired for a vessel with the same size cylinder and boiler, and an œconomy of fuel to a considerable extent *is the result.*

"I have a steamer, called the Princess Royal, on this principle in daily use in the Bristol channel, where the advantages of this method of condensing are obvious. The fuel consumed is not more than two-thirds of that used in a timber vessel with engines of equal power on the old plan, running the same distance; the speed of this iron vessel is greater by one-third, and its power to carry cargo nearly doubled.

"I have also two small passenger-boats on the Bristol dock basin, plying from Bristol to the Hot Wells, the *Expert* and *Express*, the engines of which are on the same condensing principle. Large condensers may exert a partial vacuum. The respective forms of the two vessels proves this result."

On Mechanism to explain the Pendulum Experiment. *By* RICHARD ROBERTS, *C.E.*

The first model, by reference to which Mr. Roberts explained his view of the subject, consisted of a railway upon a board, mounted on three balls, as feet, and upon that board a smaller board was mounted on four wheels like a railway waggon; upon the waggon a swan-necked piece of iron was secured, the upper end of which was bored to receive an axle representing a prolongation of the imaginary axis of the earth.

To the lower end of the iron axle a portion of a brass sphere was attached in such a manner as would admit of a dial-plate divided into 24 parts, to represent as many hours, being brought with its centre vertically over the north pole, where it might be fixed by a thumb-screw within the sphere, or at any latitude down to the equator. To the upper end of the axle was fixed a pulley, having two grooves, round each of which, in contrary directions, a small cord was passed, which was then carried through a small hole into the interior of the pulley, where it was secured. The ends of the cord were fastened tight to pillars secured one to each end of the bottom board. By this arrangement the model sphere was made to rotate by moving the waggon along the railway. Attached to the waggon, and exactly coinciding with the centre of the sphere, was an universal joint, from which a radial bar of steel extended through and a little above the dial, where it received a steel cross-bar that might be set in any direction to represent the plane of the pendulum's oscillations. Mr. Roberts contended that the phænomena in nature happened as this model showed, viz. that the pendulum would perform a revolution in 24 hours in all latitudes above 45°, or even a little below that latitude, after which it would reciprocate.

The second model consisted of a quadrant, upon the edge of which was a brass dial divided into 24 parts to represent hours. Upon a pin or stud, fixed in the centre of the dial, was a pointer, to one extremity of which a plummet was suspended, the object of which was to keep the pointer parallel to any plane that the pendulum might be caused to oscillate in; whilst the plummet will always be in the direction of the centre of the earth's gravity. To show the operation of the pendulum in all latitudes, the quadrant had been mounted upon a stand with pieces of wood jointed in such a manner that the parallelism of the pendulum to any plane in space might be seen by inspection of the model.

On a simple method of applying the Power of Wind to a Pump, for the purpose of Irrigation, as put into practice at the Cape of Good Hope. By Professor P. SMYTH.

On an Improved Modification of the Reservoir for Gold Pens. By JAMES THOMSON, *C.E.*

A slightly worn quill pen is generally esteemed the best instrument for affording quickness and ease in writing. The leading objection to steel pens is that they scratch the paper; if not when new, certainly after they have been exposed for a short time to the corrosive action of the ink. In gold pens the points may be made of any form, either fine or blunt; but if they be made as blunt as would be desirable to imitate the slightly worn quill pen, it is found that the ink is discharged in much too great quantity on the paper, and that thus the writing is blotted, and inconveniently frequent dipping of the pen is required. The reason why the capillary attraction has so much less power to hold up the ink in the gold pen than in the quill one, is to be found in the difference of form of the two pens. In the gold pen the part to which the ink adheres requires to be tapered very much to produce the requisite flexibility in so rigid a material. In the quill pen, on the other hand, the semicylindrical part extends very nearly to the point, and contains the upper part of the drop of ink. The hollow form thus given to the surface of the drop of ink in the quill pen has, according to the laws of capillary attraction, a powerful tendency to sustain the ink, while the convex form of the drop in the gold pen tends to force the ink down on the paper.

The objections thus arising to the gold pens may, however, be more than obviated by the application of a reservoir consisting of a plate or tongue of gold placed in the hollow of the pen so as to cover the part to which the ink adheres. Now a reservoir nearly fulfilling all the conditions that could be desired has been for some time in use, having been patented by Mr. Riddle and manufactured by Mr. Mordan. There are however some objections to which that particular form of reservoir is subject. It does not, for instance, admit of being opened wide enough to be easily cleaned; and from its large size it contains more ink than it can hold up with sufficient force. The new modification, which is the subject of the present paper, is free from these objections and appears to be decidedly an improvement. There is a plate or tongue

of gold attached to the pen by a hinge. The hinge allows of the tongue being opened widely out from the pen for cleaning, and also of its being turned back completely, so that the pen can be used without the reservoir, which may be desirable if a few words only are to be written, and if there should happen to be no convenient way to dispose of a reservoir full of ink when the writing is done. A sufficient tightness at the hinge to make the tongue remain in any position in which it may be placed is produced by friction between the barrel of the hinge and the pen (not between the barrel and the pin which passes through it). This friction is gained by means of a slit, distinctly shown in the figure, proceeding through the tongue from the hinge, and permitting the barrel of the hinge, originally made a little longer than the space in which it works, to be compressed longitudinally, when put into that space by the maker; so that it always tends to expand, and thus presses outwards against the pen.

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PRINTED BY TAYLOR AND FRANCIS,
RED LION COURT, FLEET STREET.

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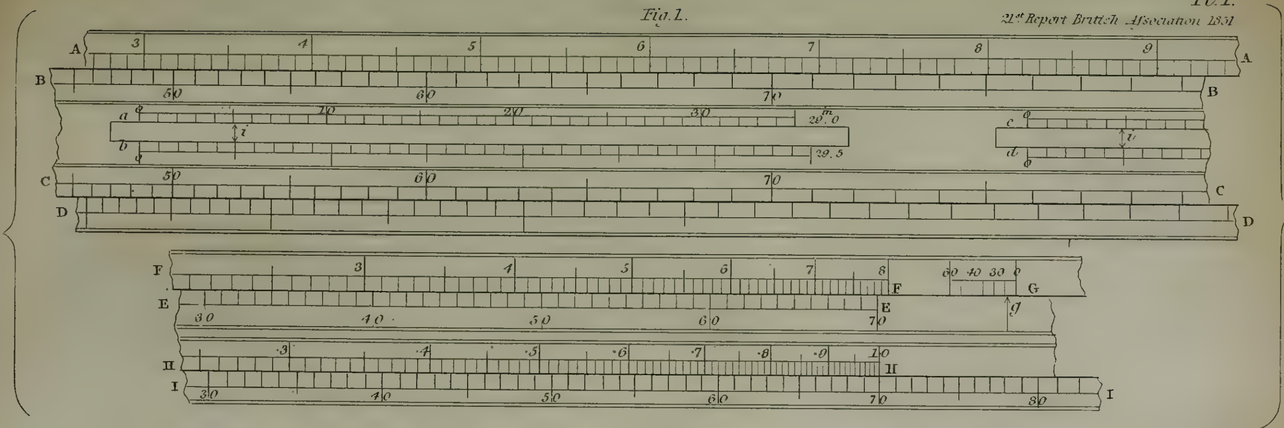

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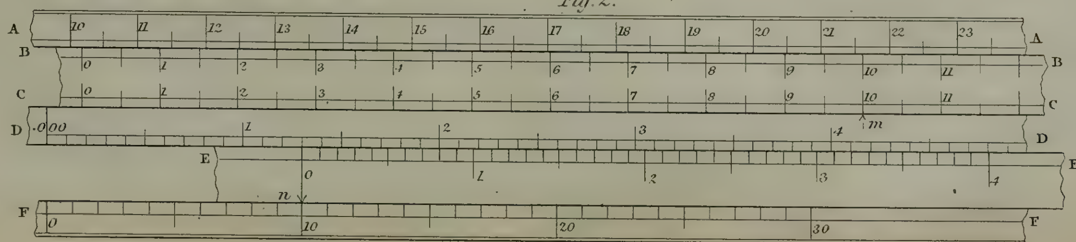

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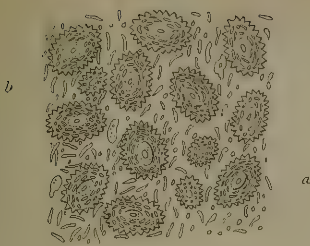

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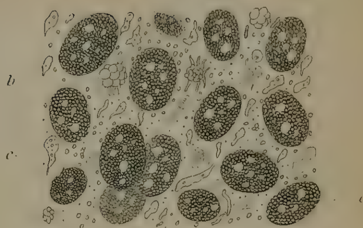

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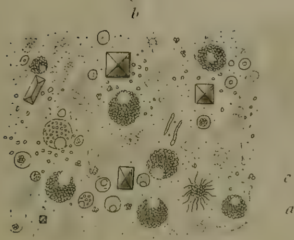

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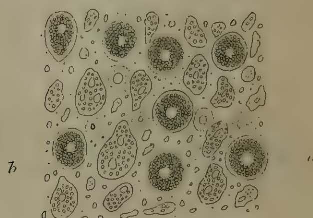

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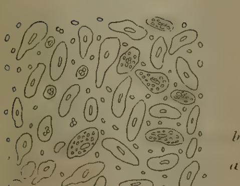

Fig. 6.

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Fig. 7.

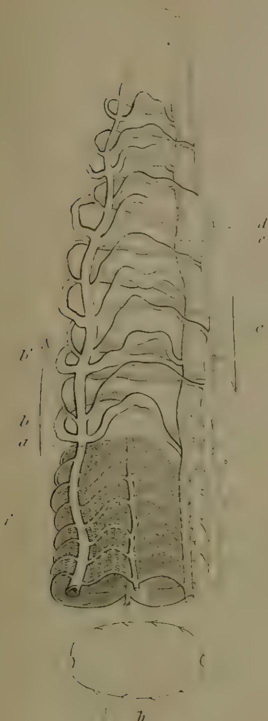
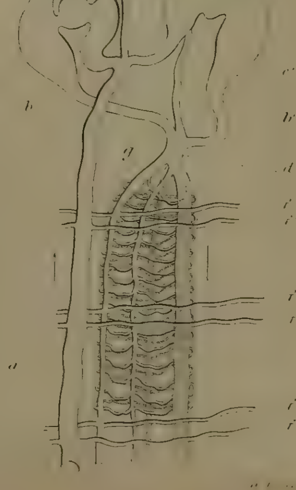
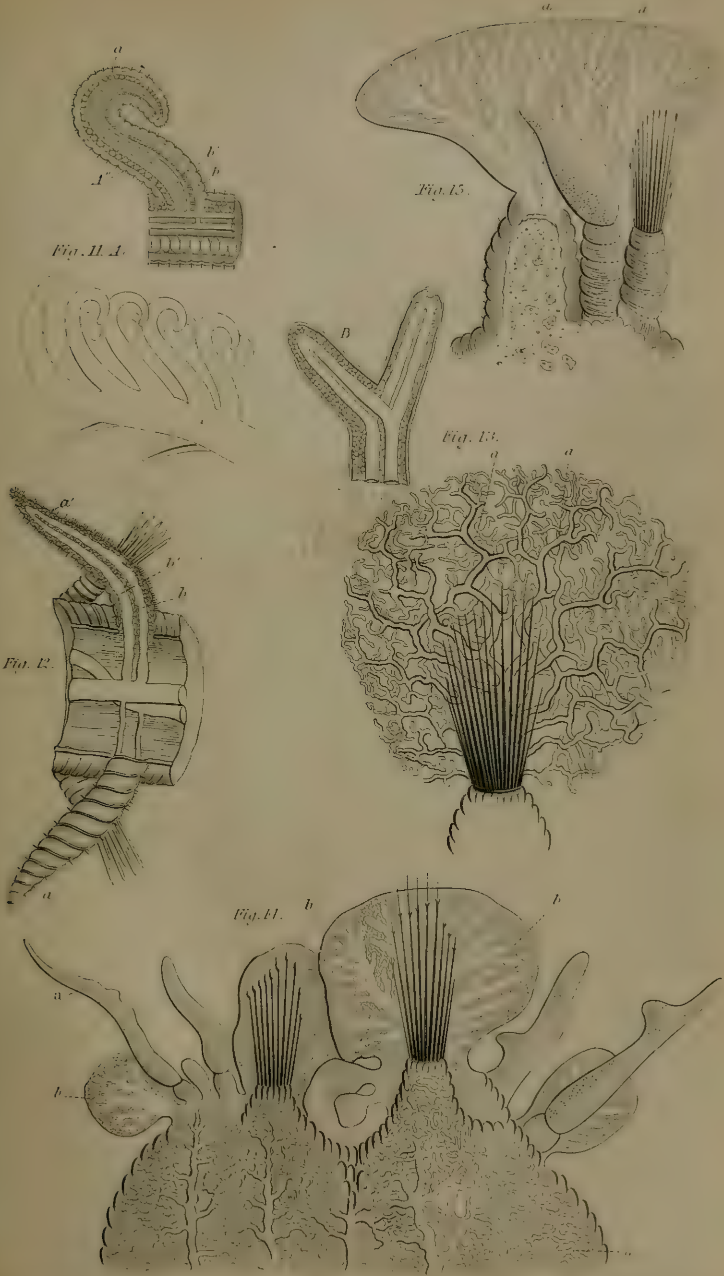


Fig. 9.

Fig. 8.

Fig. 10.





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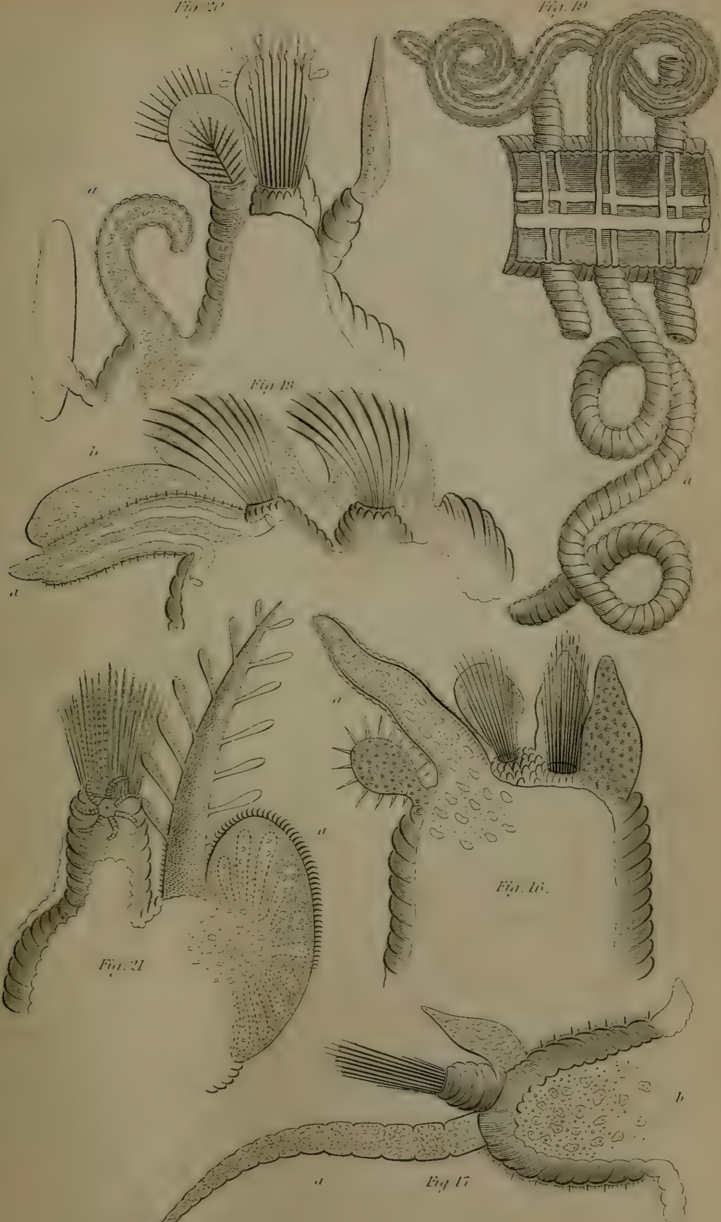

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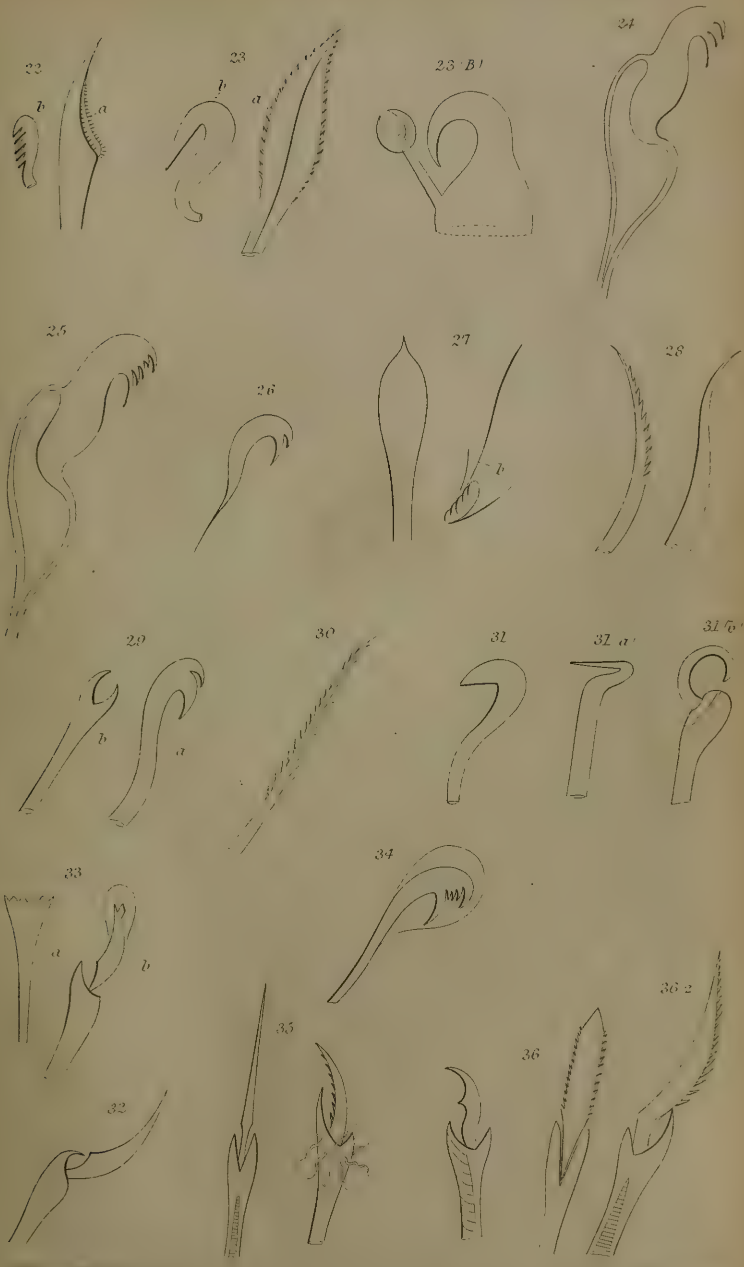

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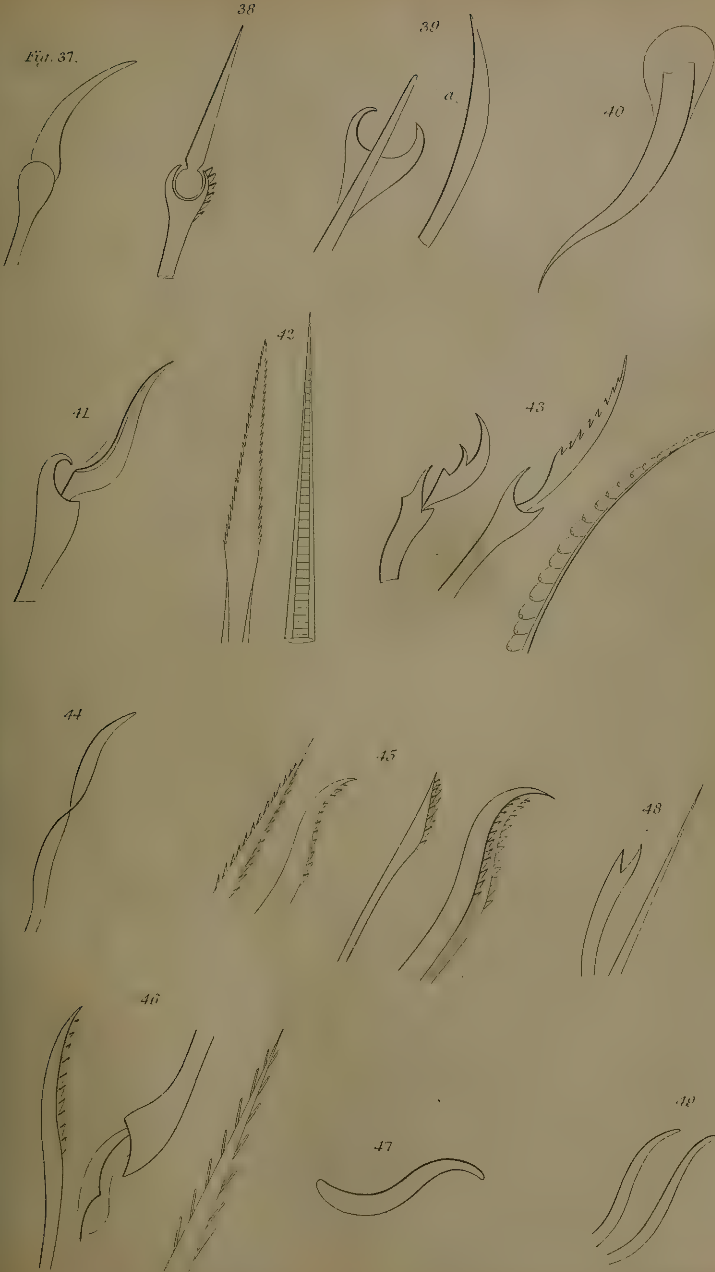

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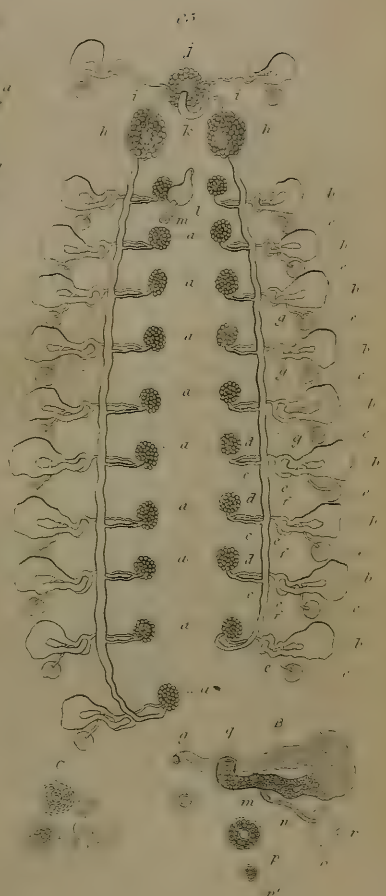

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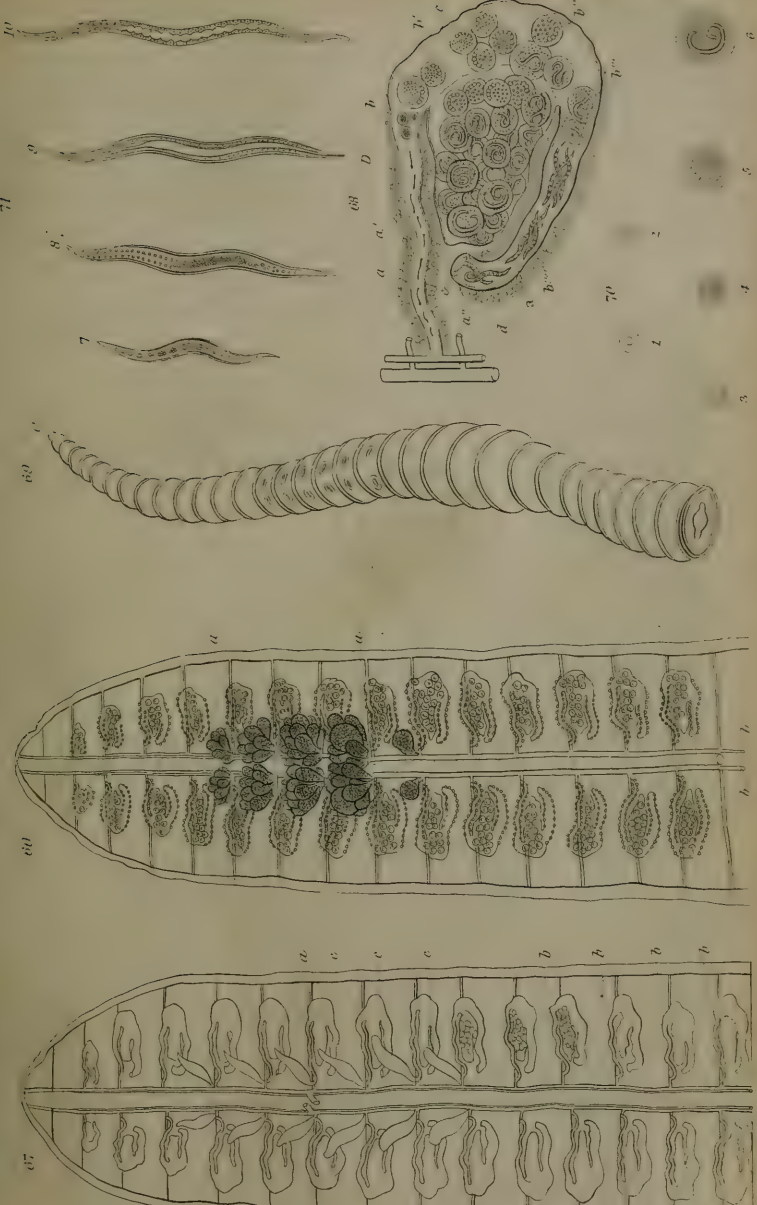

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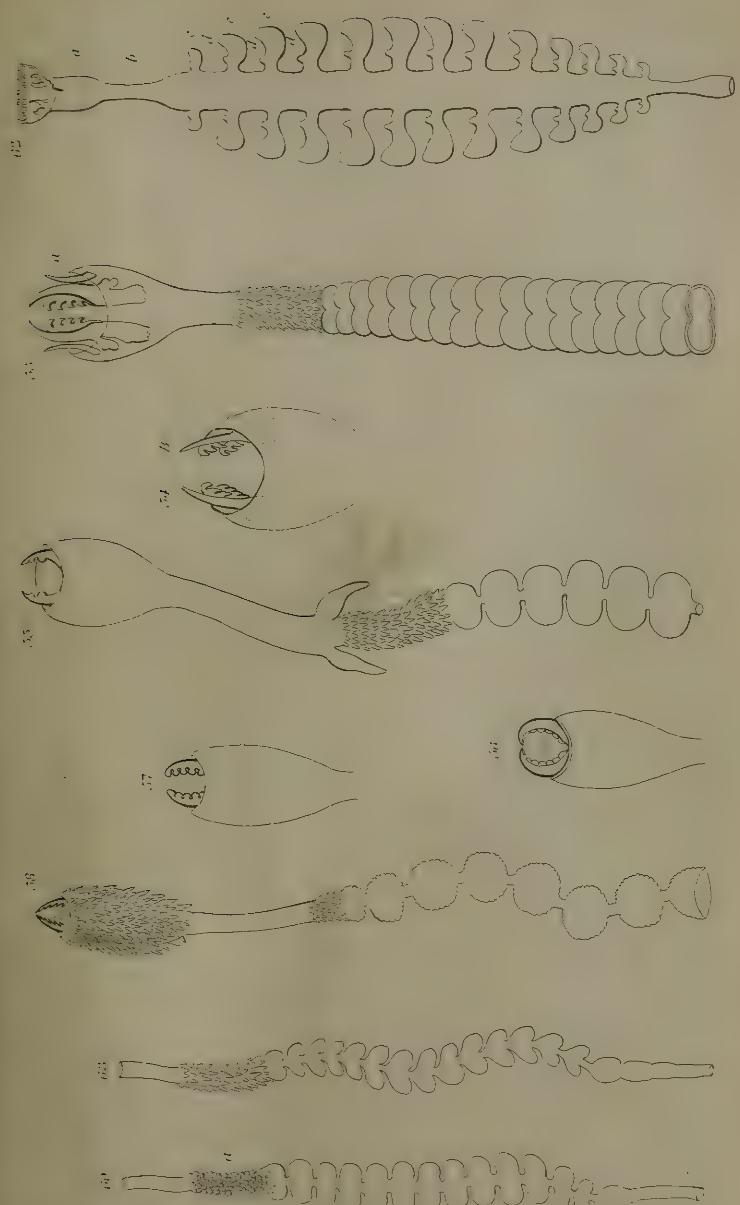

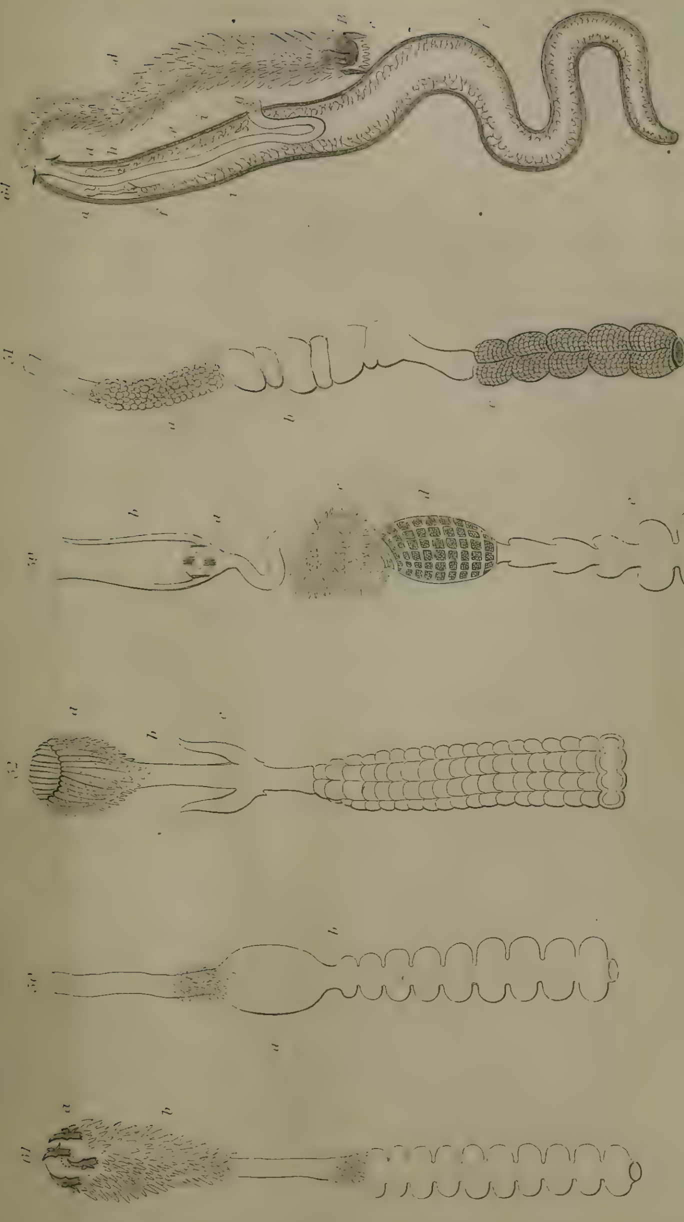

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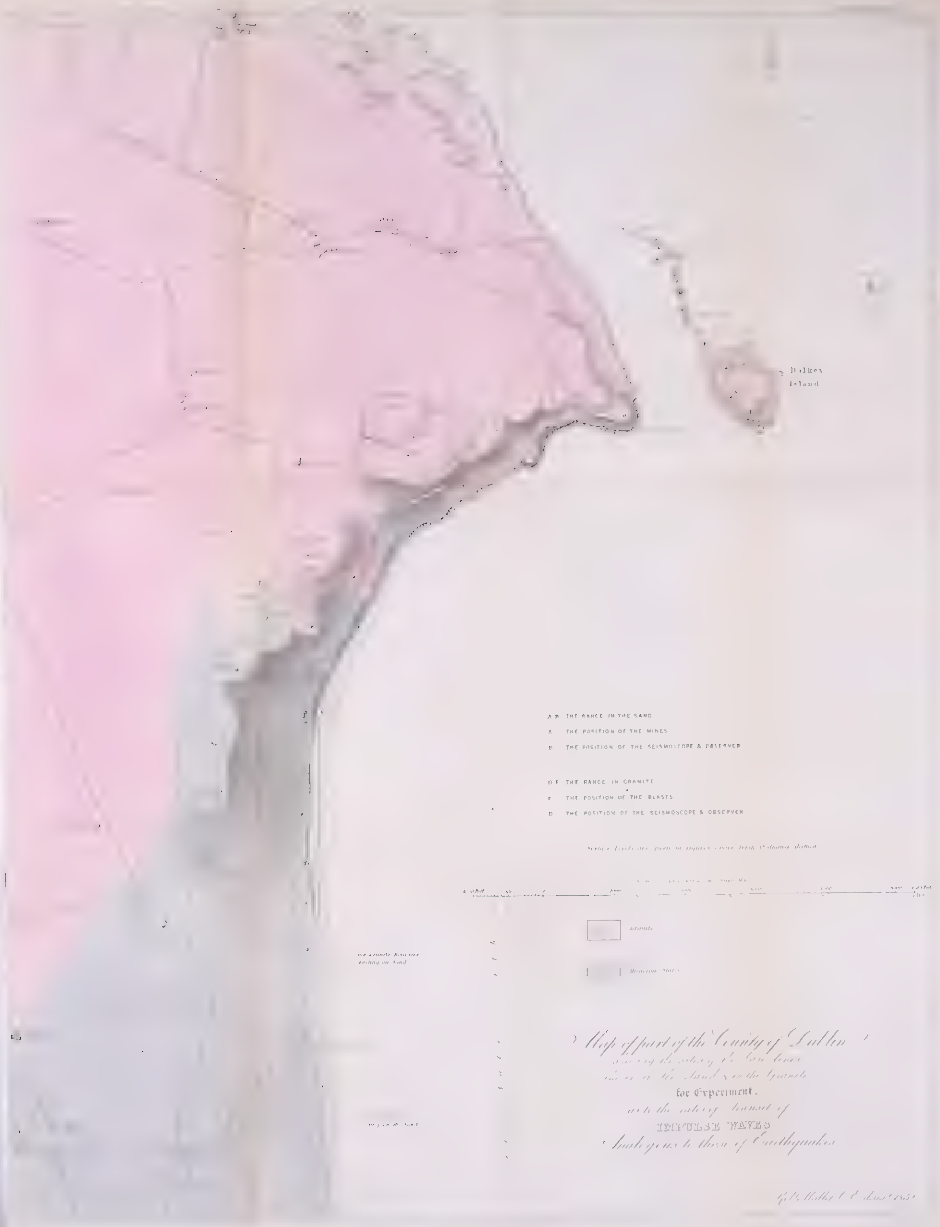
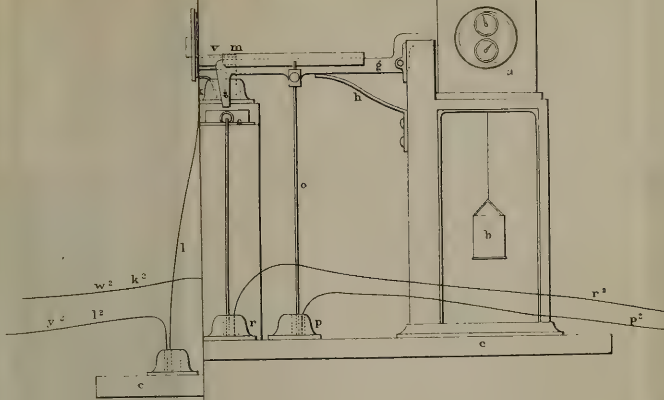

Dalkey Island
A B THE RANGE IN THE SAND
A THE POSITION OF THE MINES
B THE POSITION OF THE SEISMOSCOPE & OBSERVER
D F THE RANGE IN GRANITE
E THE POSITION OF THE BLASTS
D THE POSITION OF THE SEISMOSCOPE & OBSERVER
Granite
Map of part of the County of Dublin
for Experiment.
IMPULSE WAVES
Analogous to those of Earthquakes

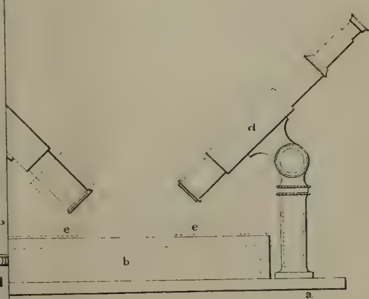
THI FIRING CHRONOGRAPH.

FIG. 2.



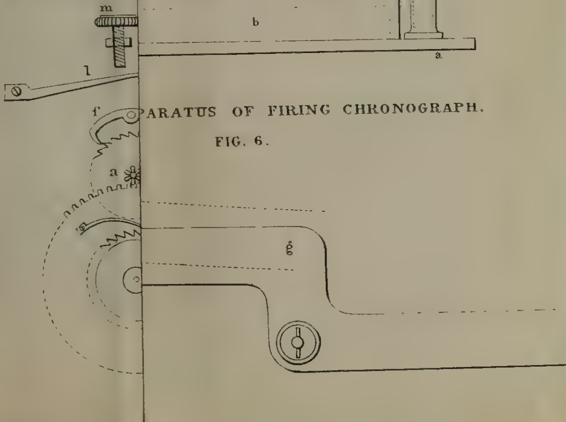
THE SEISMOSCOPE.

FIG. 3.



RELEASING APPARATUS OF FIRING CHRONOGRAPH.

FIG. 6.



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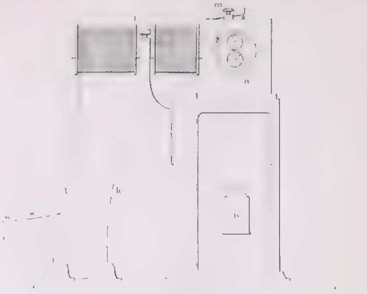
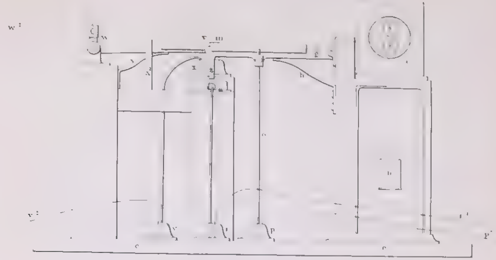
THE OBSERVER'S CHRONOGRAPH

FIG 1.



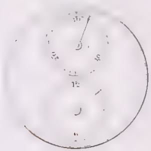
THE FIRING CHRONOGRAPH.

FIG. 2.



GRADUATION OF THE DIALS.

FIG. 4



THE SEISMOSCOPE

FIG 3

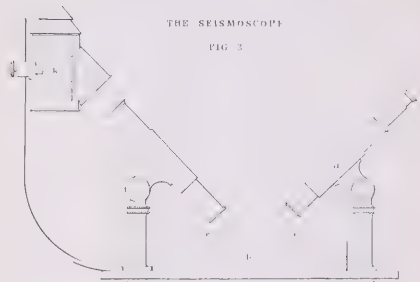


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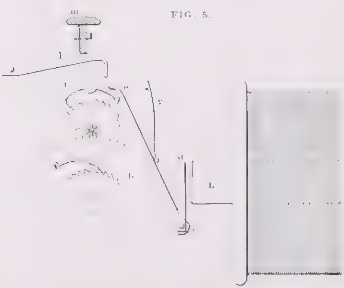
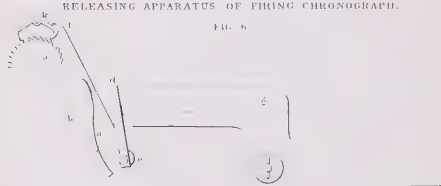
FIG. 5.



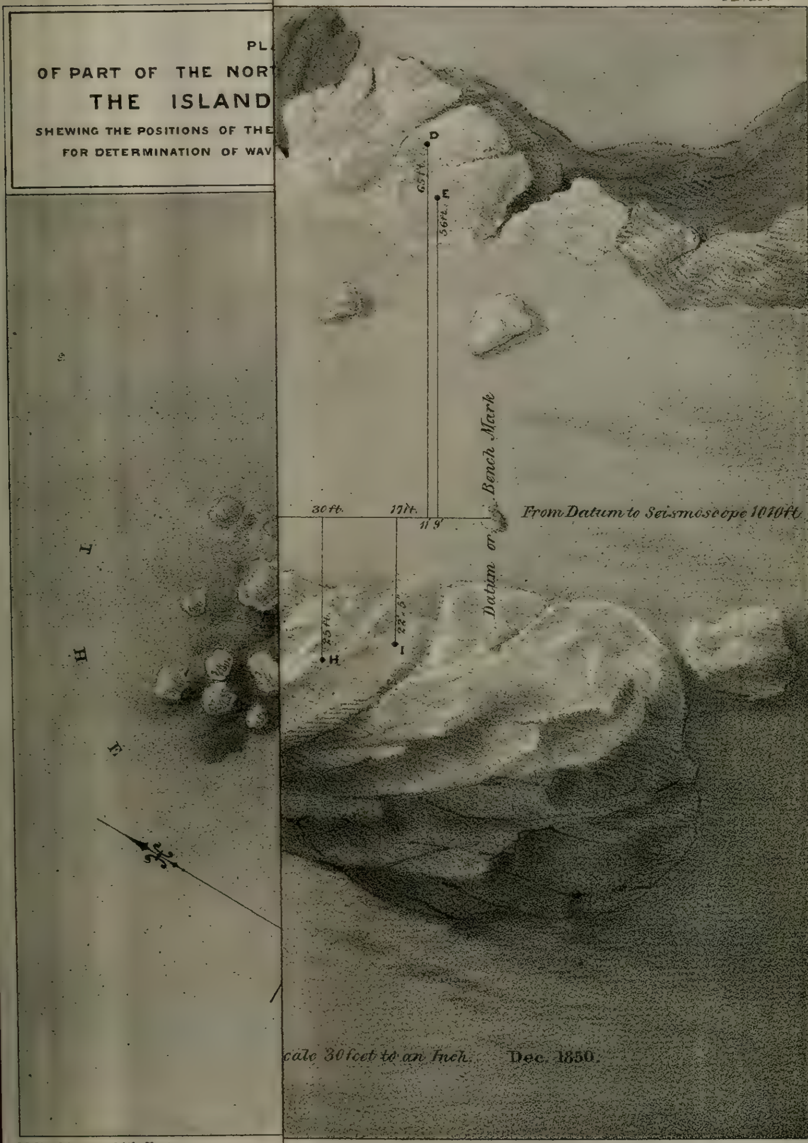
RELEASING APPARATUS OF FIRING CHRONOGRAPH.

FIG. 6

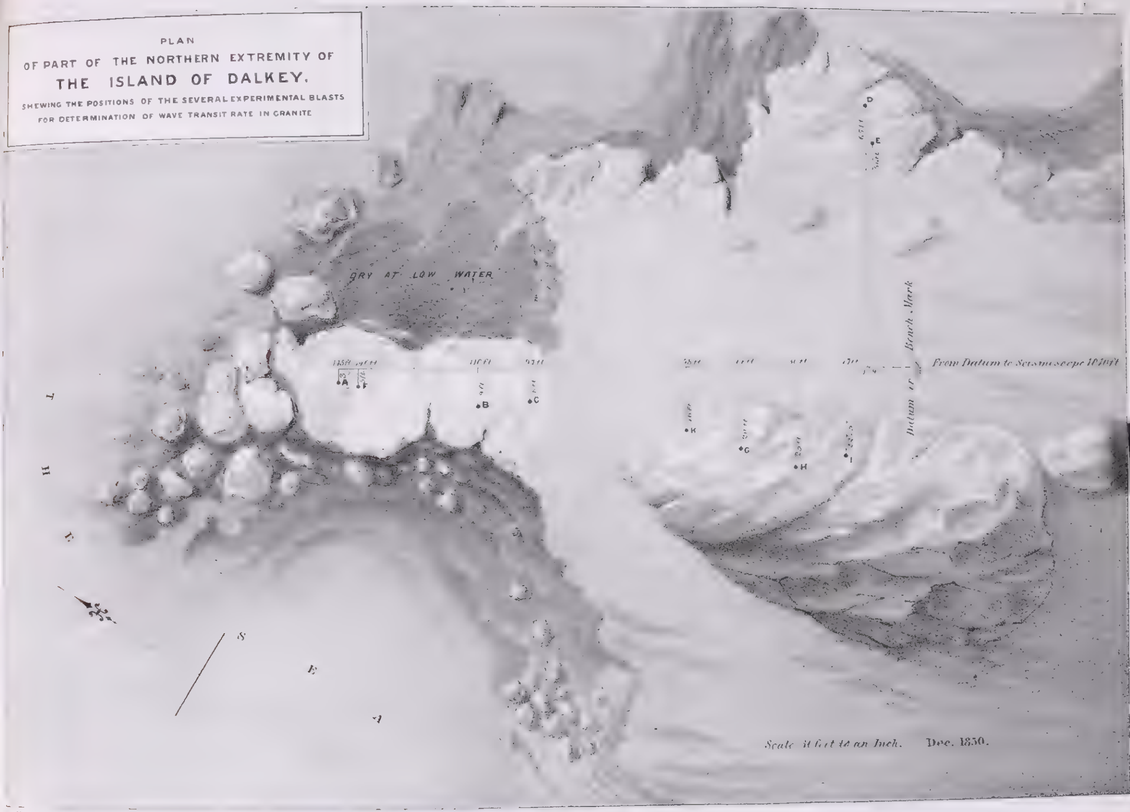


W Monkhouse Lith York

PL. XIV



W. Monkhouse, Lith. York.

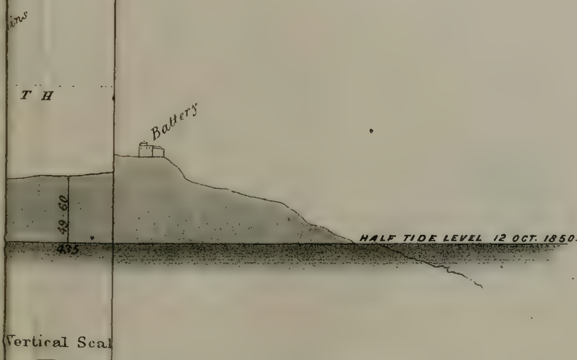


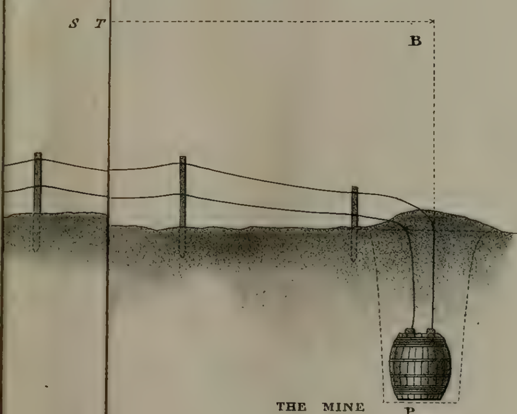
Monkhouse, Lith York

Y ISLAN

TRANSMISS

PLATE XV



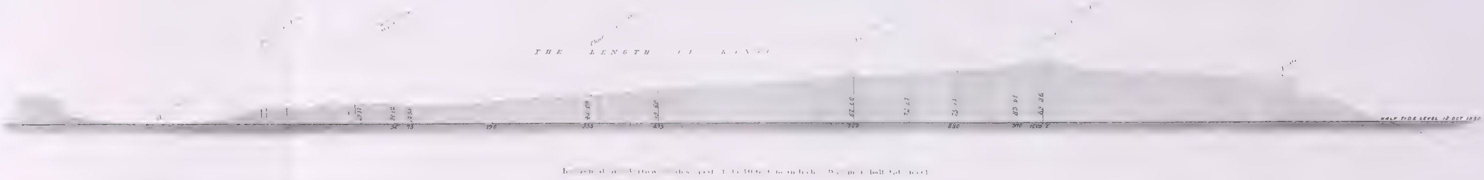


W.

PLATE XV.

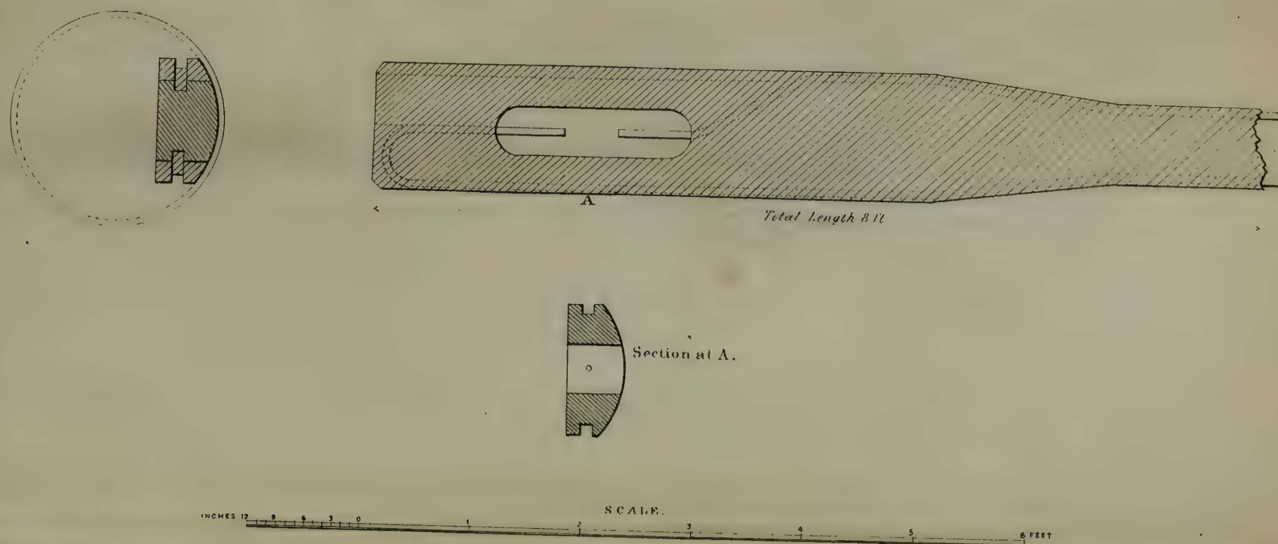
LONGITUDINAL SECTION OF DALKEY ISLAND, THROUGH THE LINE OF RANGE, CHOSEN FOR EXPERIMENTS.

AS TO THE VELOCITY OF TRANSMISSION OF WAVES OF ELASTIC IMPULSE. MADE OCTOBER, 1850.



Monkhouse, Lith York

PRIMING CARTRIDGES: EARTHQUAKE EXPERIMENTS: GRANITE.

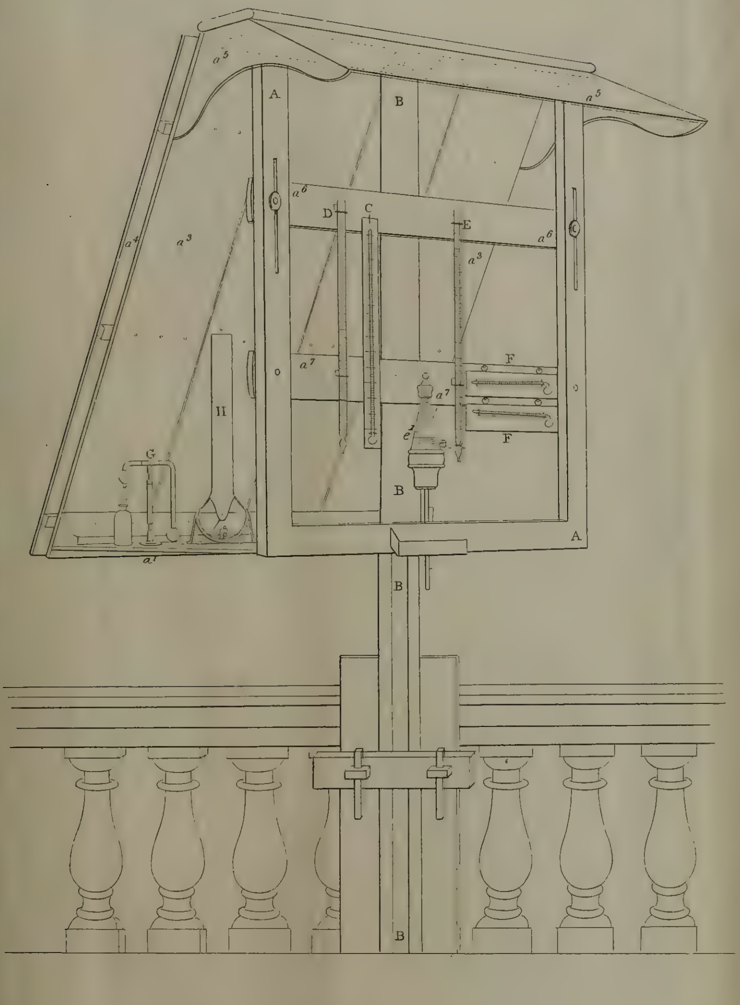


W. Monkhouse, Lith. York.

NOTICE.

Plate XVII., a Map, to illustrate Mr. Mallet's Report, has been subject to an accident in the colouring. Corrected copies will be delivered with the continuation of the Report.


B
D



J. Basire sc.

Fig. 2.

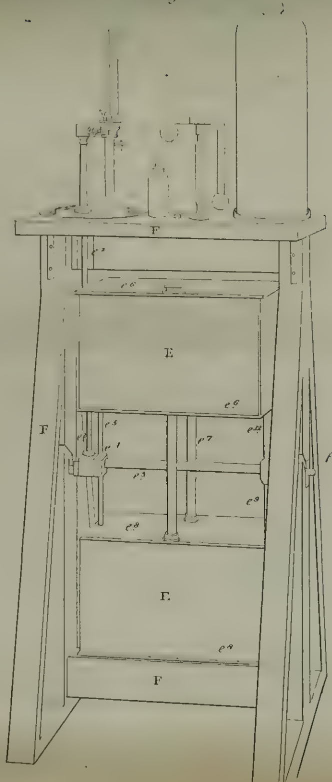


Fig. 1.

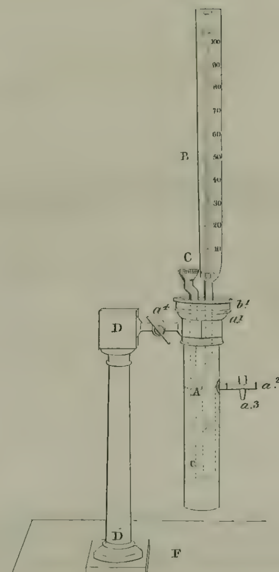
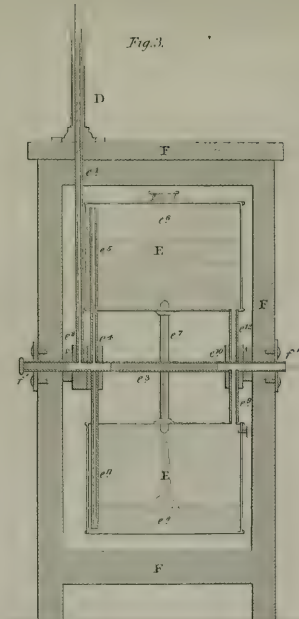
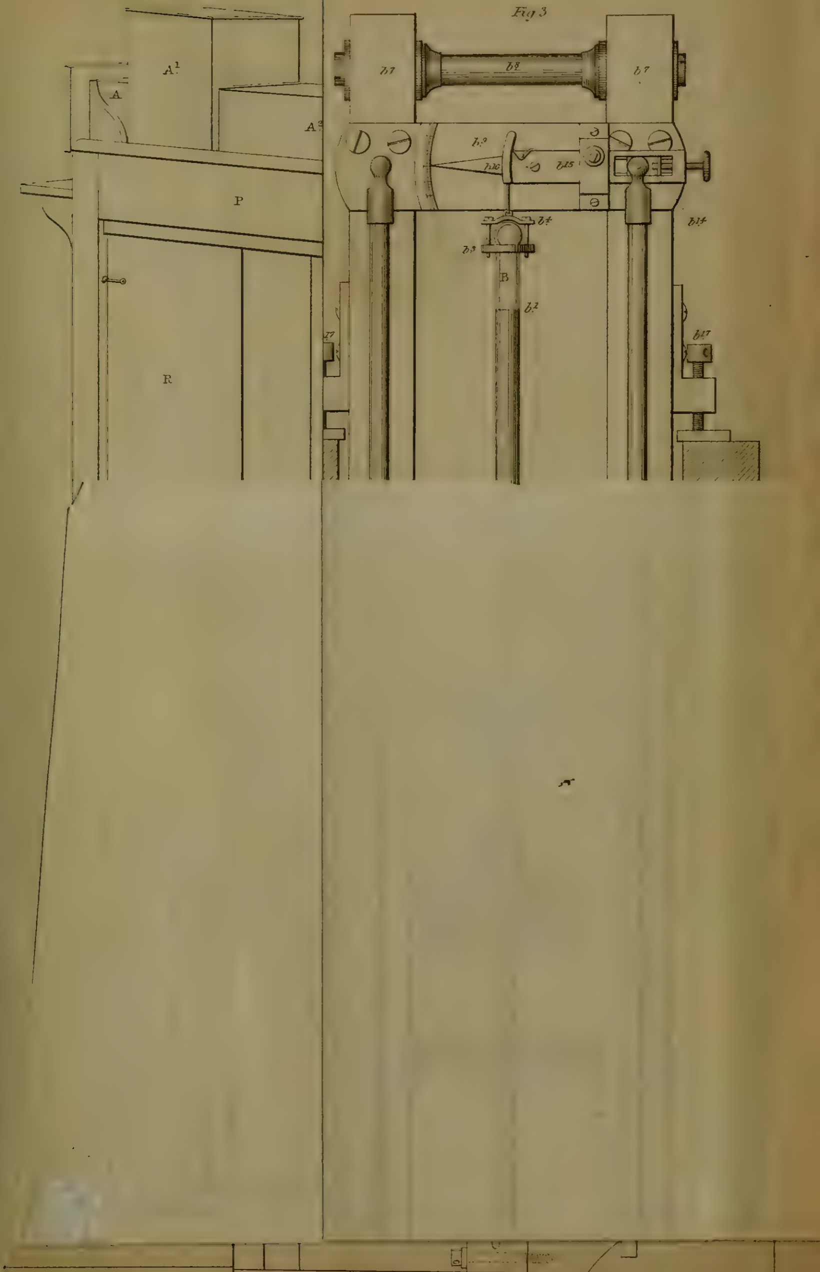


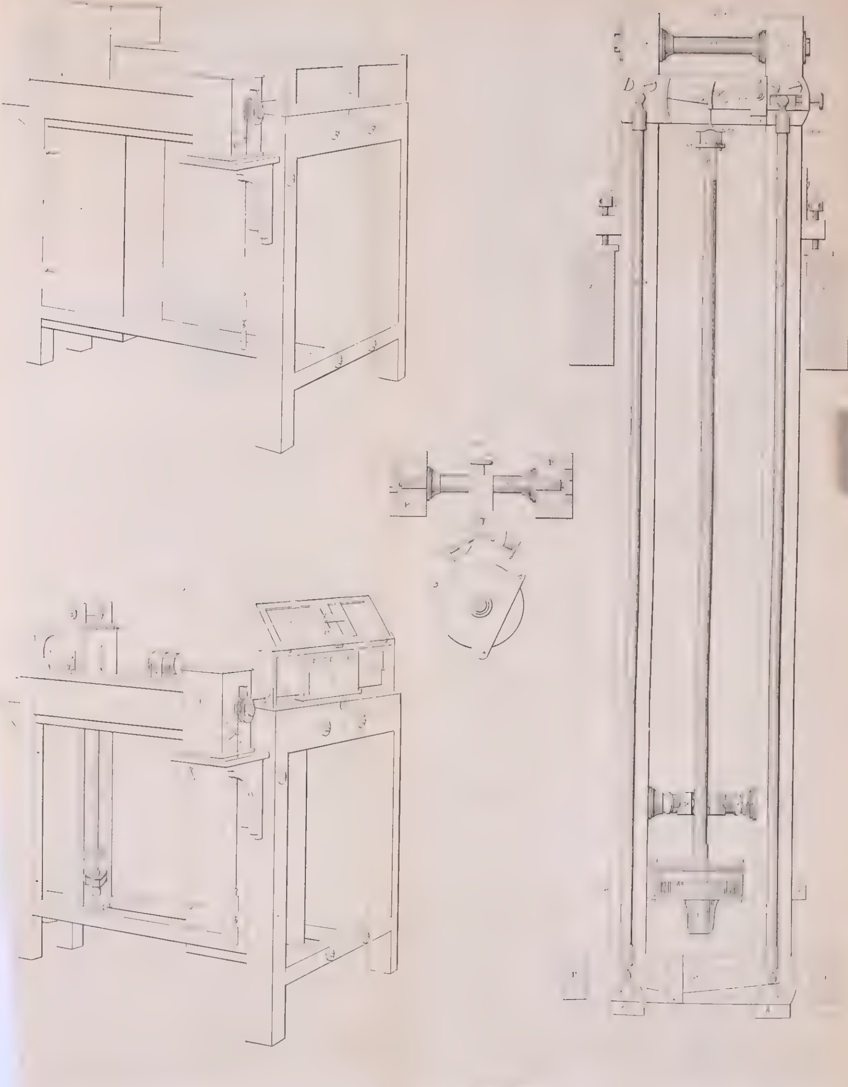
Fig. 3.



J. Basire, sc.

Fig 3





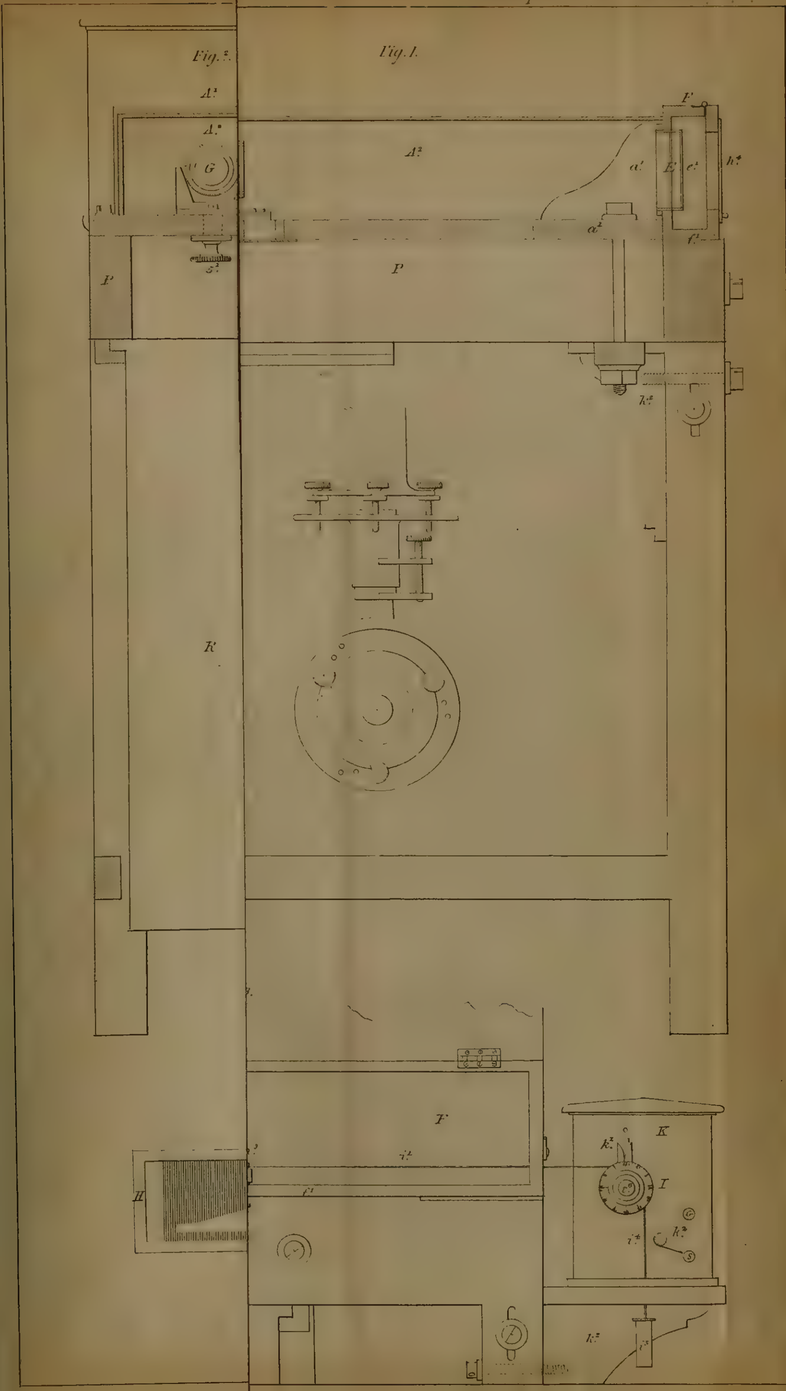


Fig. 2.
Fig. 1.
A²
A⁴
G
F
a¹
E
e¹
h⁴
a²
f¹
P
P
s²
h²
K
F
i²
f¹
H
K
k¹
I
i⁴
k³
k²

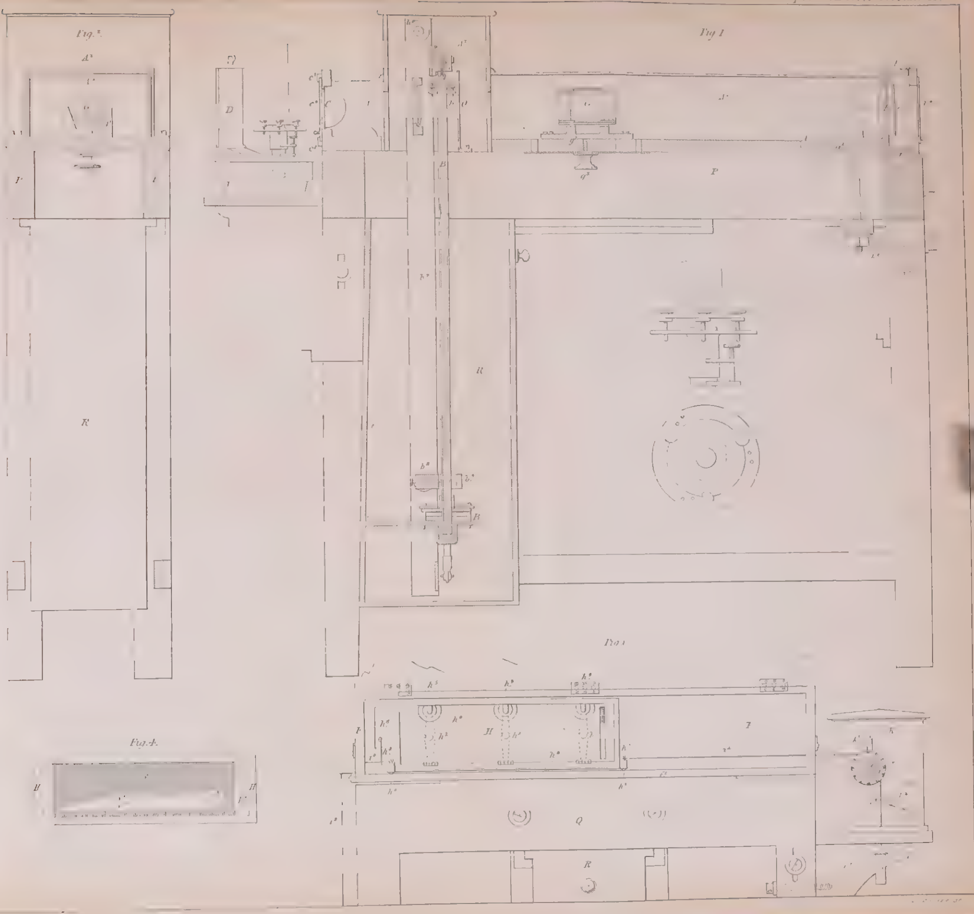
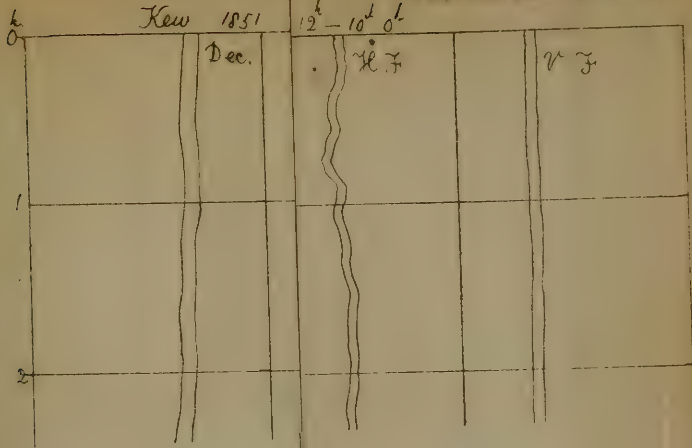


Fig. 1
Fig. 2
Fig. 3
Fig. 4.


Kew 1851 12h – 10d 0h
h.
0
1
2
Dec.
H. F.
V. F.